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Climate History of Hungary Since 16th Century: Past, Present and Future

by

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In memory of Antal Réthly

FOREWORD

The history of this booklet begins as far back as March 1985 when, as a second-year university student of both geography and history, I was trying to find a topic for my research work that was related to both sciences. My university professors, *László Makra* and *György Péczely* introduced me to the reference work of *Antal Réthly*. During my university studies *Gábor Mezősi* acted as my tutor, while the first studies I made were commented on by *Vera Zimányi*, *Ágnes R. Várkonyi*, *Sándor Gyimesi*, *László Katus*, *László Kordos*, *János Mika* and *János Justyák*. In 1990 I was fortunate enough to make contact with the prominent actor and coordinator of European climate history research, Professor *Christian Pfister*, who played a very dominant role in my professional career. At Prof. *Pfister*'s invitation I worked at the Department of Regional and Environmental History of the University of Bern in the 1990's. During my studies in Bern *Christian Pfister* and *Hannes Schüle* introduced me to the method of using documentary sources, while the availability of adequate software and hardware resources further supported me in my ongoing research work. In addition to the climate history work completed in Bern, I enjoyed the benefit of considerable assistance in my research from historians such as *Bernard Lepetit* and *Jean-Yves Grenier* of 'École des Hautes Études en Sciences Sociales' in Paris. The final impetus to produce this booklet was provided by the Hungarian Scholarship Committee ensuring a two-month scholarship in the Czech Republic at the end of 1998. The manuscript of this edition was prepared at the Geographic Institute of the Masaryk University in Brno with the assistance of Professor *Rudolf Brázdil* and *Petr Dobrovolný*.

Brno, 12 December 1998

Lajos Rácz

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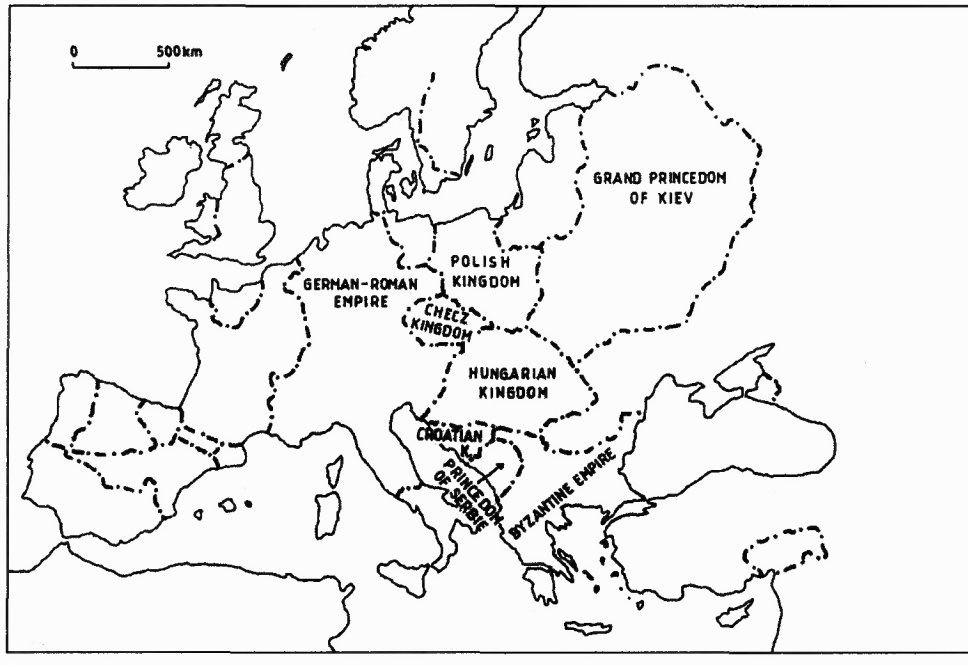
1. TERRITORIAL VARIATIONS OF THE HUNGARIAN STATE SINCE 1000 AD

The Hungarian tribes reached their final homeland, the Carpathian Basin during one of the last migrational waves at the end of the 9th century. The 300,000 square kilometer area of the Carpathian Basin became the geographical site of the Hungarian State for centuries.

Figure 1 *Central Europe in the 11th century*

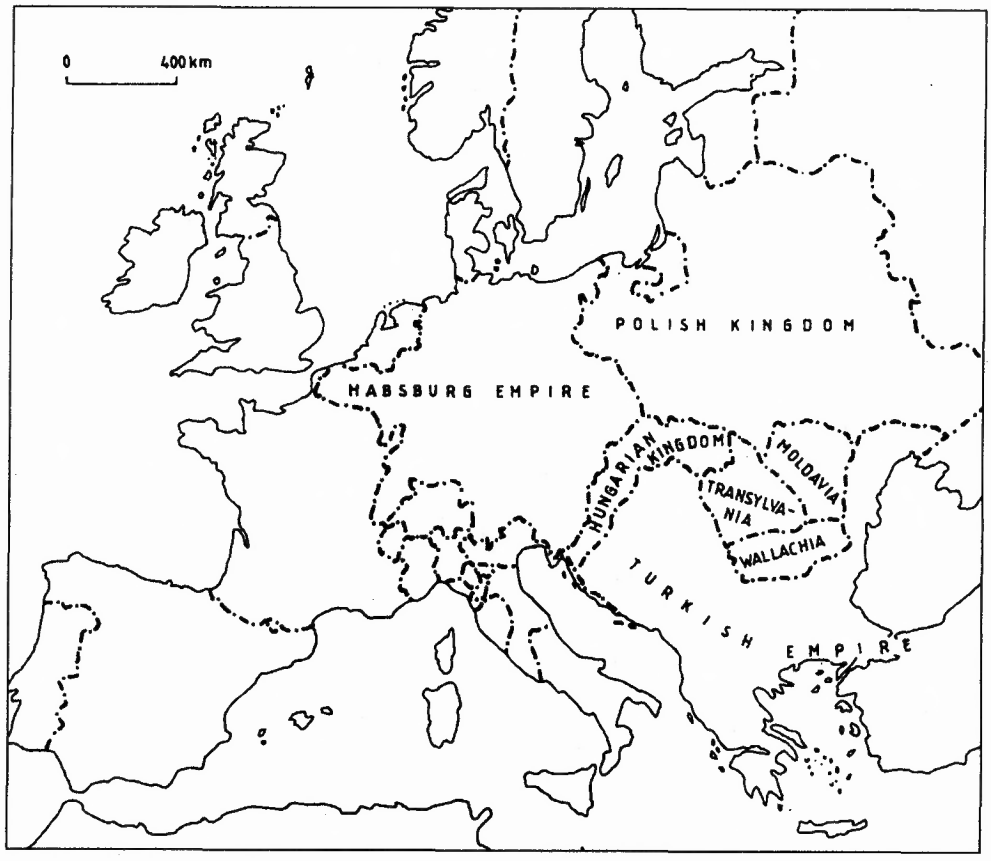


(St.) Stephen I (István) (997-1038) officially adopted Christianity in 1000 AD and founded the Hungarian Kingdom. In the Middle Ages the area of the country gradually expanded following several conquests and inheritances. In the 12th century the Croatian crown went to the Hungarian king as the Croatian royal family died out. The Croatian-Hungarian personal union endured until the beginning of the 20th century. The Hungarian State occupied the largest amount of territory in the Middle Ages when, in the 14th century, the Hungarian King *Lajos I the Great* took the title of King of Poland.

Figure 2 *Borders of the Hungarian Kingdom in the 14th century*

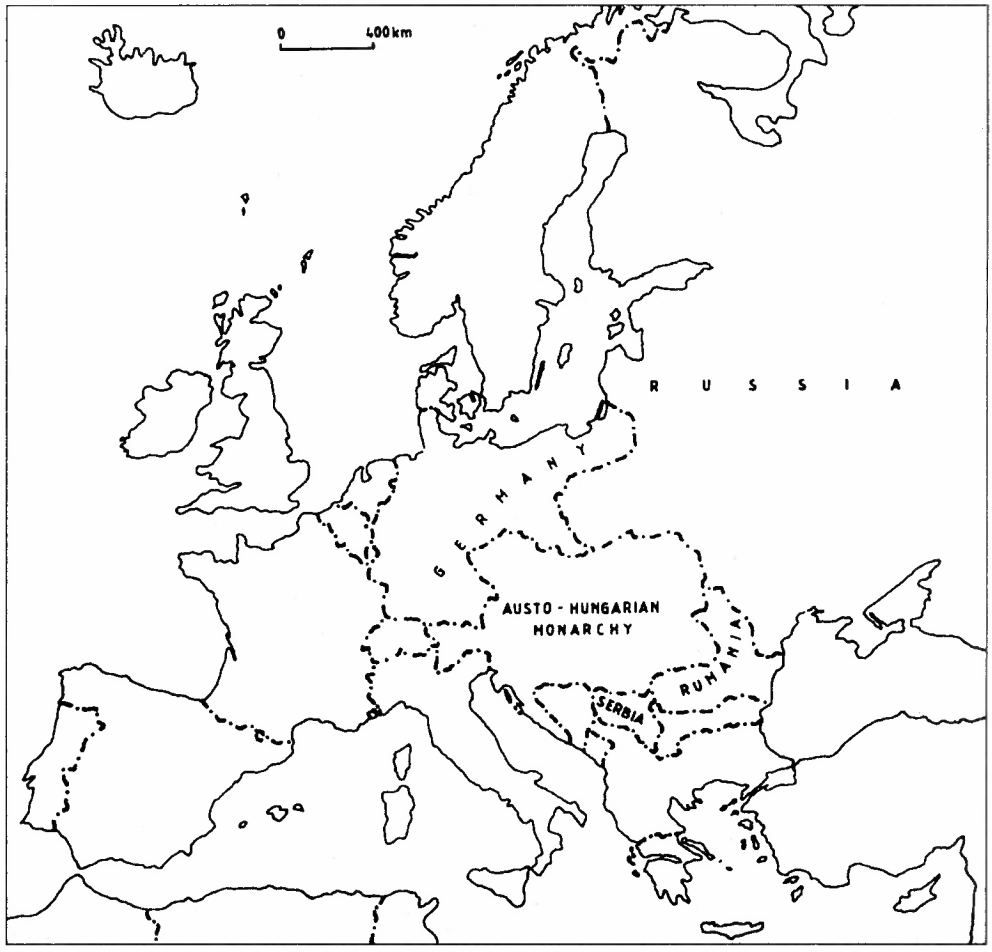
In the 15th century the Turks appeared at the southern border of Hungary and conquered the southern and central territory of the country after a struggle of one and a half centuries, while the eastern territory, Transylvania, became a Turkish satellite-principality. The Hungarian Kingdom was then limited to the northern and northwestern regions of the Carpathian Basin and became part of the Central European Habsburg Monarchy together with Croatia.

Figure 3 *Changes in the territory of the Hungarian Kingdom in the age of the Turkish wars (1541-1686)*



The territories occupied by the Turks were finally liberated at the end of the 17th century. By this time the Hungarian Kingdom had lost its independence, but retained a special status within the Central European Habsburg Empire. Following several political disagreements, uprisings and revolutions the Habsburg Empire in the Compromise of 1867, which created the Austro-Hungarian Monarchy, finally officially acknowledged this special legal status.

Figure 4 *The territory of the Hungarian Kingdom during the Austro-Hungarian Monarchy*



The Austro-Hungarian Monarchy ceased to exist as a state as decided in the peace agreements ending the First World War when a division into the quasi-national states of Austria, Czechoslovakia, Yugoslavia, Hungary and Romania replaced the empire. Following the decisions of the peace agreement, Hungary became an independent state while losing two thirds of its former territory, and the map of Hungary has not significantly changed since that time.

Figure 5 *Central Europe in the 1990s years*

When analyzing the climate history prior to the end of the First World War the territory within the Carpathian Basin was studied, while in the later decades of the 20th century the area under study relates to the present day territory of Hungary.

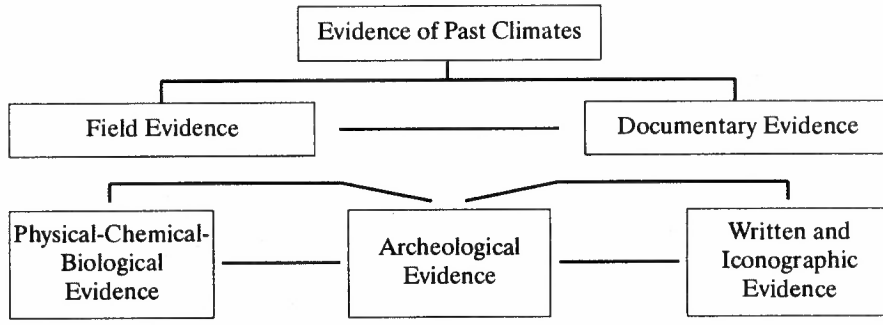
2. SOURCES FOR HUNGARIAN CLIMATE HISTORY RESEARCH

In our country Budapest has the longest running records of meteorological instrumental observation with temperature records dating back to 1780 but these records do not contain associated adequate precipitation data prior to 1841. The second longest running records dates back to 1853 and is from Debrecen, despite the fact that the network of meteorological stations in most places in Hungary was not created until the last third of the 19th century.

The determination of meteorological conditions for time periods which pre-date recording of instrument based observations belongs to the sciences of climate and environmental research, while its sources are generally characterized as proxy data in the specialized literature. These sources can be quite varied. The first major group covers sources based on physics, chemistry and biology, and the first national climate reconstruction based on a database of this type was the 'vole-thermometer' by *László Kordos* (1977) which makes it possible to follow the climatic changes in Hungary during the 12000-year Holocene geological age.

The second major proxy source-group includes the archeological sources, and in this respect the dendrological studies by *András Grynaeus* (1997) deserve special attention, however the combination of the dendrochronological 'floating' time series and their climate related interpretation has yet to be completed.

Figure 6 *Sources of information for the reconstruction of past climates. The separate categories often overlap, and some of the more important interactions are shown. (Based on Ingram, M.J. (1981) et al.)*



The third major source-group includes archives, irrespective of their being written, photographic or cartographic in nature. With regard to climate related historical sources we enjoy especially favourable conditions in the Central-European region, thanks primarily to the research activities coordinated and directed by the former

manager of the National Meteorological Service, *Antal Réthly*. *Réthly* and his colleagues collected information from available sources concerning climate historical descriptions and indications in Latin, German, Turkish and Hungarian. The resulting works were published later in three volumes by the research manager, out of which the Akadémia Publishing House edited the first two in 1962 and 1970. Approximately half of the third volume was edited by *Antal Simon* and was issued as a publication of the National Meteorological Service in 1998.

The prototypes for *Réthly*'s climate history sources admittedly originated with the German climate historical school. *Réthly* even used *Hennig*'s (1904) and *Weikinn*'s (1958) Hungarian related source work. The question must be raised as to what extent the doubts, formulated by *Emmanuel Le Roy Ladurie* (1967), *Pierre Alexandre* (1987), *Christian Pfister* (1984) and other researchers of philologian education towards elements of the German school, are relevant in relation to *Réthly*'s sources. Researchers specializing in History have been critical of the work of researchers having an education based in meteorology and geography pointing to alleged mistakes in chronology and sources from a historical point of view. In the case of *Réthly*'s collection we can be assured of chronological accuracy as *Réthly* was well aware of the dating system commonly used in the Middle Ages which disappeared from use during the centuries of Modern Times. The calendar reform by *Pope Gregory XIII* in 1582 took effect in the territory of the Hungarian Kingdom in 1588, yet it became generally accepted only around 1625, while the old calendar remained in use in the territory under Turkish occupation until the latter third of the 17th century. *Réthly* (1962) dealt with the problems arising from the mixed use of the different calendars and with the application of recalculation methods in the first volume of his work. The integrity of *Antal Réthly*'s scientific interpretation of sources is further assured by his extensive experience, having been engaged in archive research since the early 1900s, publishing his first study on climate history in 1914 in the Hungarian meteorological paper 'Időjárás' (Weather). *Réthly* also consulted with outstanding historians in relation to his work. For example in interpreting Turkish sources he consulted with the professor of Oriental Studies, *Gyula Germanus*, who was the first Hungarian to complete the pilgrimage to Mecca, and when working with Hungarian sources related to the problematic Modern Times, he consulted with *Flórián Holovics*, Chief Archivist. In his references *Réthly* classified the different sources as to their reliability, with sources of a lower level of reliability printed in smaller fonts along with appropriate comments. Similarly, conflicting sources were also pointed out. *Antal Réthly*'s excellent education in meteorology combined with his extensive practical experiences was quite beneficial to his work with the various reference literatures. *Réthly*'s comments on climatology were most useful when interpreting the phenomena of nature described in the documentary sources.

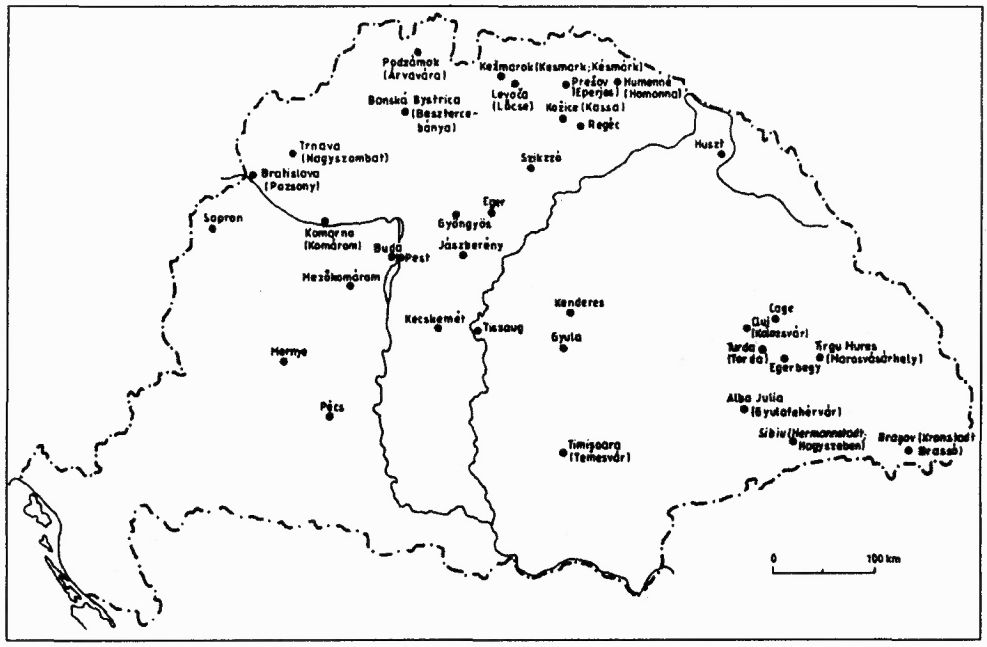
2.1. Documentary Sources of Réthly's Source Book

In the first volume of *Antal Réthly*'s source book the earliest reference to a weather report for the Carpathian Basin states that the Danube was covered with ice in 173 AD, but for purposes of a thorough historical reconstruction of climate, adequate sources are only available beginning with the latter half of the 16th century. The most reliable reference sources for historical climate information varied during different periods of modern times, and *Christian Pfister*'s form and content standardization methods were used in reviewing the various sources.

Table 1 *Types of climate history sources and information*
(Based on Pfister, Christian (1984): Klimageschichte der Schweiz, Bern)

type of information		type of documentary sources						
		chronicles, annals	evidence of public administration	evidence of private estate	Personal notes	Early journalism	Early instrumental records	instrumental records
description of weather		weather anomalies	damages	weather anomalies, damagies	weather anomalies, trends, damages	weather anomalies, trends, damages	systematic description of weather	systematic description of atmospheric events
instrumental observation							temperature, precipitation, atmospheric pressure	temperature, precipitation, atmospheric pressure
Biological information	phenological	cereals, grapevine	cereals, grapevine	cereals, grapevine, hay	cereals, grapevine, hay	cereals, grapevine, hay		
	para-phenological	date of vintage	tithe records, date of wheat harvest and vintage	date of wheat harvest and vintage	date of wheat harvest and vintage	date of wheat harvest and vintage	date of vintage	
	wine-growing evidence	quantity and quality of wine	quantity and quantity of wine	quantity and quantity of wine	quantity and quantity of wine	quantity and quantity of wine	quantity and quantity of wine	

Figure 7 *Venues of historical climate observations in Hungary*



2.1.1. Chronicles, Annals

Chronicles

The chronicle-sources in Hungary can be divided into three categories: *national chronicles, regional chronicles* and *town chronicles*. The division is mainly based on the extent of the geographical area described, however the various types of chronicle communicate very different information in content as it relates to the analysis of climate history. Environmental and climate related observations are hardly mentioned in the text of the *national chronicles*, and only then as external factors which tended to facilitate or impede war-related events. The *regional chronicles*, however, do go into some detail regarding climate, relating important details and events such as extreme weather conditions and disasters, as well as relating prevailing weather conditions to perennial agricultural success or failure. With regard to climate history the best sources are the *town chronicles* as people in the cities were at the mercy of the outside world on a daily basis, living in a special symbiosis with their agricultural environment. It is therefore no surprise that the individuals responsible for writing the town chronicles, who in many cases were also high-ranking officials in their towns, dealt with agriculture and weather at length in their writings.

The chronicles represent the only sources for reconstructing climate history in the 16th century, but their informative character gradually lost importance in later centuries as a result of the expansion of the written form.

National Chronicles

Miklós Istvánfi (1535-1615) was the only chronicler to view events from a national point of view. Istvánfi, statesman and historian, wrote the chronicle *'Pannonii historiarum de rebus ungaricis...'* in Latin dealing with the history of Hungary between 1490 and 1606.

Regional Chronicles

As a chronicle of regional character of the war-related events of the 16th century, the diary of *Suleyman, the Magnificent* (Ottoman Sultan: 1520-1566), despite the misleading title, is a work of historical significance and quite useful.

Máté Sepsi Laczkó (-1624), theologian and historian of Transylvania, authored a history of Transylvania for the period from 1520 through 1624. *Lestár Gyulafy* (1157-1605) also dealt with the history of Transylvania, but his chronicles in Latin (Ephemerides) were lost and only the records used in the preparation of the chronicle remained. *István Szamosközi* (-1612) was the most outstanding humanist historian of Transylvania, who served first as archivist in Gyulafehérvár, later as court-historian of *Prince Bocskai*, and his life's work was to wrote a history of Transylvania, which unfortunately remained unfinished.

Albert Bielz's (1817-1898) chronicles from South Transylvania is also regarded as a regional source but it contains both the regional and town chronicles in German of the Saxon towns (the most important were: R-Braşov, G-Kronstadt, H-Brassó; R-Sibiu, G-Hermannstadt, H-Nagyszeben) in Transylvania and thus is somewhat of a blend of regional and town chronicles.

Town Chronicles

During the Turkish era Sopron was the only town in Western Hungary that did not fall under Turkish occupation. This was a result of its strategic military location, Sopron has the richest source of climate history of all Hungarian towns. The Bruckner chronicle is in fact a collection of the German chronicles of Sopron edited by *Gottlieb Bruckner* in the first half of the 19th century, listing the events of the town from the 15th century until his own era. Another series of chronicles from Sopron were the chronicles by *György Payr* and *Mihály Payr*, also in German, these authors wrote the history of the town from 1586 until the end of the 17th century. The chronicle by *Márk Fauth*, Councilor of Sopron deals with a shorter period, but it is a very detailed chronicle of the period from 1579 until his death in 1616. Fauth's chronicle was subsequently completed with events from later centuries.

My most significant source in reconstructing the climate history of the Highlands is *Gáspár Hain*'s chronicle from Levoča (H-Lőcse). *Hain* (1632-1687) was the chief constable of this town who collected the earlier Saxon chronicles and continued them until

his death. His life's work was published in German under the title *'Zipserische oder Leutschauerische Chronica'*.

Sebestyén Borsos (1520-1584) was the chief constable of Tirgu Mureş (H-Marosvásárhely) from 1565 through 1582 and using the town chronicles that had been written earlier, he edited the history of Tirgu Mureş (H-Marosvásárhely) from 1490 through 1583.

Yearbooks

Within the category of yearbooks the most useful sources for climate history information from the early Modern Times were diaries from the monasteries of the Order of Jesuits and the 'historia domus' from the Franciscan monasteries. Depending on their interests, the monks writing the books dealt with weather conditions to differing extents, but generally speaking, thanks to these sources there are already periods in the last third of the 17th century for which a precise climate history can be reconstructed.

In the first volume of his collection *Réthly* published the records of the Latin diary from the Monastery of the Order of Jesuits in Levoča (H-Lőcse) for the periods 1673-1679 and 1686-1706. Also the first volume of *Réthly*'s collection contains the records of the Latin diary from the Monastery of the Order of Jesuits in Košice (H-Kassa) concerning the period 1677-1681. Further volumes of the diaries from the monasteries of the Order of Jesuits have to this day remained unavailable.

In addition to the works compiled by the Order of Jesuits, the Franciscan Order established and maintained a countrywide network in Hungary during the early Modern Times. The 'Historia Domus' of the Franciscan Order in Gyöngyös has daily weather records starting from 1706 through the end of the 18th century. The Historia Domus from the Franciscan Order in Eger dealing with the period 1765-1800 is included in the second volume of *Réthly*'s collection. Complementing the historia domus from the monasteries in Gyöngyös and Eger, *Réthly* also used records for the 18th and 19th century from the historia domus of the monasteries in Mernye, Kecskemét and Jászberény.

2.1.2. Records of Public Administration

The public administration archives have not yet been studied from the point of view of climate history, and *Réthly*'s collection includes only some of the ordinances issued by the Imperial Council. Further research in this area would be very useful.

2.1.3. Private Estate Records

The source-group of private estate records includes manorial records by their economic officials. In these records the writers concentrate mainly on the results of agricultural production acknowledging the general opinion that 'weather is the real boss everywhere'.

Réthly's collection contains only a few private estate records, one of the exceptions being the records from the manor of *Prince Trautsohn* in Regéc which were used by *István Bakács* (1930).

2.1.4. Personal Papers

Thanks to the expansion of written literature the most important source group in my climate history research includes personal papers beginning in the second half of the 17th century. This source group can be basically divided into two types: private letters and personal diaries. The letters and extracts of letters included in *Réthly*'s collection are mainly from the correspondence between the aristocrats of Transylvania and Hungary containing mainly private and sometimes political and military information with some reference to weather and climate data. The diaries were written by townspeople, priests/clergymen of congregations and noblemen with farms who paid significant attention to the weather. Besides giving detailed accounts of the weather, agricultural production facts and figures were also recorded together with prevailing market prices.

Typical examples of this type of correspondence from the early Modern Times were the letters from *Count Mihály Teleki* (1905-26), *Prince Miklós Eszterházy* (1909), *Prince Gábor Bethlen* (1886) and *Prince György Rákóczi II* (1877).

Our first diarist was *Zsigmond Torda*, an officer of the Hungarian Treasury who finished his medical studies at the University of Padova. He kept a diary in Latin in which records for the period from 1558-1568 are available. *Torda* worked at two seats of the Royal Chamber, in Bratislava (G-Pressburg, H-Pozsony) and Prešov (H-Eperjes), and he recorded his observations while in these towns and while traveling between them.

György Dobronoki (1588-1649) was the first Rector of the University in Trnava (H-Nagyszombat), studied in Graz, and later joined the Order of Jesuits. As Viceroy of the order he worked in Zagreb, Trnava (H-Nagyszombat) and Humenné (H-Homonna). *Dobronoki* wrote his diary in Latin on a daily basis and his records for the period 1636-1638 are available to us.

Ambrus Keczer (1620-1671) was in *István Thököly*'s confidence, the father of *Prince Imre Thököly*. In his diary he wrote about the fortresses and towns of the Highlands including Podzámok (H-Árvavára), Kežmarok (H-Késmárk), Prešov (H-Eperjes) and Huszt. The volume of *Keczer*'s diary covering the period 1663-1669 was preserved.

Of particular value to researchers of Hungarian climate history are the war records of *Prince Imre Thököly* (1657-1705). The prince experienced many adventures and maintained a diary from the age of 19, in which he described the weather in detail every day. It is quite unfortunate that only parts of his diary remain available to us today, mainly for the years 1676-1678, 1685-1686, and 1689-1694.

Another valuable resource document for climate history information is the diary of *György Czegei Vass* (1644-1705), a Transylvanian politician and landowner from Cege. *György Czegei Vass* started writing a diary in 1680 and continued doing so until his death in 1705. Six years later, in 1712 his son, *László Czegei Vass* resumed his father's tradition writing a diary for the next 26 years, until 1738.

The diary of *Zsigmond Szaniszló*, town clerk of Torda, includes daily weather reports as well as a monthly and seasonal analysis of general weather conditions. Records from *Szaniszló*'s diary have been preserved only for the period 1682-1711.

An important source of climate history in the Highlands from the middle third of the 18th century is the diary of the Körtvélyesi Pap Family. *István Körtvélyesi Pap* (-1757), judge of the town of Szikszó initially began writing this diary, which was continued after his death by his son, *István Körtvélyesi Pap Junior*, a Calvinist pastor. From this family diary we have the volumes from the period 1745 through 1779 which contain general annual evaluations in the records up until 1757, but subsequent to that date, when *István Körtvélyesi Pap Junior* took over the writing, daily observations of weather conditions are recorded as well.

The diary by *István Debretzeni Pap* (-1841), a Calvinist pastor also contains references to weather in varying detail, however it mainly contains general annual evaluations and daily observations are only infrequently included. *István Debretzeni Pap* started writing his diary in 1807 as a pastor in Tiszaug and in 1815 he became the head of the congregation in Kenderes, working there and continuing to write his diary until he died in 1841.

László Zlinszky (1801-1862), the Chief Engineer and Chief Director of Road Affairs in Pest County, started writing a diary rich in weather observations in 1821, and continued his recording until his death in 1862. The diary contains mainly general monthly and seasonal evaluations, while the daily records refer exclusively to unusual weather events.

The diary of *Mihály Király*, Calvinist pastor of Egerbegy in Torda County, written between 1823 and 1848 now represents an important source for Transylvanian climate history research. In the diary he recorded daily reports as well as a monthly weather summary.

Like his fellow-pastors from Kenderes and Egerbegy, *Gábor Ecsedy*, the Calvinist pastor of Gyula also wrote daily diary recording detailed weather conditions for the period. 1834-1852 and this diary, having been preserved in it's entirety is available for reference purposes.

Ferenc Váli, Director of the Calvinist College in Komárom, also recorded detailed daily weather observations in his diary for the period from 1841 through 1846 and these records remain available to this day.

2.1.5. Early Journalism

The newspapers starting to appear towards the end of the 18th century became more and more important with regard to reconstructing climatic history. It started with the German paper 'Pressburger Zeitung' published in Bratislava (G-Pressburg, H-Pozsony) first in 1764 and continuing for the longest time in the history of the Hungarian press was published through 1929. The first paper in Hungarian was the 'Magyar Hírmondó' (Hungarian Messenger) which appeared between 1780 and 1788. Another Hungarian newspaper with the same title was published in Vienna between 1792 and 1803. The most important one published in Hungarian in Vienna was the 'Magyar Kurír' (Hungarian Courier) between 1788 and 1834.

In addition to Bratislava (G-Pressburg, H-Pozsony) and Vienna the first newspapers in Pest-Buda came out at the turn of the century. The German language paper 'Vereinigte Ofner und Pester Zeitung' made it's debut in 1798 and was published until 1845. An interesting chapter in the publishing history of Hungary was written in the period between 1790 and 1793 when the Latin language newspaper 'Ephemerides Budenses' was published. The most important paper published in Hungarian in Pest-Buda was titled 'Hazai és Külföldi Tudósítások' (Local and Foreign Reports) published first in 1806, and continued after 1840 under the title 'Nemzeti Újság' (National Paper) after 1840 before ceasing to exist in 1848.

These early newspapers obtained the news partly through the correspondents' network, and partly through subscriptions to European papers. The major benefit to my research provided by a review of these twice-weekly newspapers was the excellent overview of the weather conditions throughout the country during the relevant period.

2.1.6. Early Instrument Based Records

At the turn of the 18th century lecturers and doctors educated in natural sciences paid more attention to regular weather observation. The first doctor in Hungary to make regular weather observations was *Andreas Loew* (1666-1710), Chief Scientist of Sopron. *Loew* made his notes in Latin and his observations were included in the collected works of the English doctor, *Sydenham*, published in Geneva in 1769. *Sydenham*'s volumes also included the weather observations of the medical Doctor *Raygeri* who worked in Sopron and Bratislava (G-Pressburg, H-Pozsony) and was therefore most certainly a colleague of *Loew*'s for some time. After *Loew*'s death, *János Ádám Gensel* (1677-1720) continued the Sopron observations, and was elected Vice-Chairman to the German 'Academia Naturae Curiosorum' in 1719. *Gensel* was the first Hungarian observer to measure the temperature and air pressure several times a day in the early 18th century, and his records were also included in *Sydenham*'s collected works.

Nearly all of the meteorological authors of Hungary in the first half of the 18th century had their reports published in the German periodicals of natural science of that age. The first Middle-European scientific paper for the 'meteorologists' of Hungary was the 'Sammlung von Natur und Medizin...' published in Wrocław (G-Bresslau), which later was taken over by the publication 'Nachrichten – Miscellanea Physico-Medico-Mathematica, oder angenehme, curieuse und nützliche...' published in Erfurt. These papers printed observations by *István Pál Bácsmegyei*, a doctor from Banská Bystrica (H-Besztercebánya), *György Buchholtz*, a polyhistorian from Kežmarok (H-Késmárk), and *János Ádám Reimann*, 'Senior Physicist' of Sáros County and Prešov (H-Eperjes).

Sámuel Benkő (1743-), 'Senior Physicist' of the Town of Miskolc and Borsod County, who studied at the university of Trnava (H-Nagyszombat) and Leiden, commenced detailed meteorological observations in 1780 reading the thermometer and barometer several times a day between 1780 and 1802. In Timişoara (H-Temesvár), the pharmacist *József Károly Klapka* (-1817), started his meteorological observations also in 1780 and continued reading the temperature and air pressure three times a day for 24 years. *János Genersich* (1761-) who completed his university studies in Jena commenced meteorological observations in 1789 as a teacher of the Lutheran lyceum in Kežmarok (H-Késmárk). While he left this job in 1800 for unknown reasons the records of the University of Vienna show that Professor *Genersich* was invited as a lecturer in 1821.

Detailed records of temperature and air pressure readings for Buda are available for the years 1811 and 1812. Little is known about the person who made these recordings, other than the fact that he was a citizen of Buda with a legal education.

The men of the Patkovich Family in Pécs made meteorological observations for more than 70 years. *Boldizsár Patkovich*, who graduated as a doctor from the University of Vienna and shortly afterwards was appointed the health officer of Baranya County, started recording his observations in 1781. His eldest son *József* also studied at the medical faculty of the University in Vienna graduating in 1809 and, in 1831, he was also appointed the health officer of Baranya County. After his father's death, *József Patkovich* continued keeping the weather records through 1853.

Antal Hódosi Karácsony, a landowner and amateur natural scientist performed meteorological observations in Mezőkomárom from 1835-37 and in Székesfehérvár from 1837-1847. *Karácsony* recorded the temperature and air pressure several times each day and wrote short comments on changes in the weather in his meteorological diary.

2.1.7. Meteorological Instrument Records

Systematic meteorological observation in Hungary commenced in 1755 at the University of Trnava (H–Nagyszombat) under the direction of *Ferenc Weisz*, Professor

of Mathematics. *Queen Maria Teresia* (1740-1780) had the university relocated in 1777 to the royal castle of Buda. It was at this time that the astronomical tower was built in the castle to serve as an astronomical and meteorological observatory. As of New Year's Day in 1780 meteorological readings were taken here, at first with instruments brought from Trnava (H-Nagyszombat), and then from 1781 onwards with instruments provided by the 'Societas Meteorologica Palatinae' in Mannheim. The university was once again relocated from Buda to Pest, but the meteorological observatory remained in the Castle of Buda. The temperature, precipitation and air pressure were recorded in Buda from 1780 onwards, and notes on cloud-cover were also included in the records. Uninterrupted time series are available only for temperature from the very beginning, but as of 1841 the records included precipitation time series as well.

When using the time series from Budapest, I had to take into account the consequences of the observatory relocation and as well as the effect on meteorological observations of Budapest becoming a metropolis. In order to compensate for these distorting effects, I used the time series homogenized by *Tamás Szentimrey* (1944) in my analysis.

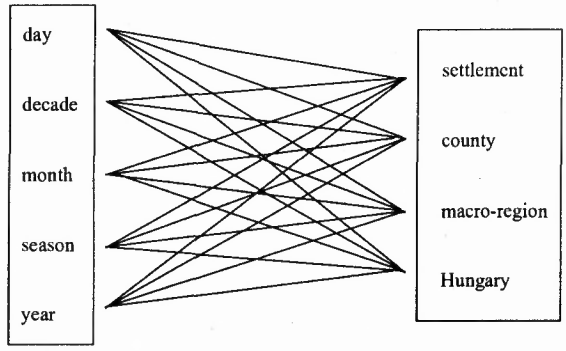
2.2. Method of Analyzing the Source Documents

In order to combine the historical climate information from the various documentary sources with that in my routine climate analysis, the sources had to be rearranged according to theme, geographical location, and dates. To facilitate this procedure I used the program of the Clim-Hist computer climate history databank developed by *Christian Pfister* and *Hannes Schüle* at the Historical Institute of Bern University. The first step in the procedure was to classify that information which related directly to the weather according to themes, following the coding principles of the Clim-Hist system. The second of the three main groups of information which had to be sorted was indirect weather data such as the freezing or rise of the river, while the third major information group consisted of phenological data related to the natural environment and agricultural society. When grouping the sources according to time, five time scales were used as follows: single day, unit of ten days, month, season and a whole year. The four geographical categories used for arranging the data were as follows: settlement, county, the four macro-regions (Transdanubia, Highlands, Transylvania, and Great Plain) and the country as a whole.

After arranging the documentary sources I excluded those sources that provided information judged to be too general in nature. I only used those sources where the writers clearly described the weather, ecological, or phenological events, and where their time frames were determined with at least monthly accuracy. This way I excluded those sources providing general statements on the season and weather such as 'winter is very cold, summer is very hot'. It is quite evident that by employing this method I

also excluded some authentic documentary sources from the analysis, but I believe the resulting database is more reliable as a result.

Figure 8 *Spatial and temporal structure of climate history reconstruction in the Carpathian Basin*



After having grouped the reference data on climate history information, this data was expressed numerically. In this phase of the analysis I followed the methodology of *Christian Pfister*: more specifically, each weather incident from the data base was marked on a scale +/-3, whereby +3 means extraordinary warm and rainy, while -3 indicates extraordinarily cold and dry weather. In the course of my research I created temperature and precipitation time series for days, units of ten days, months, seasons and for the whole year for each of the settlements, the counties, the four macro-regions of the Carpathian Basin and for the country as a whole.

I would be remiss were I not to address the following question here: to what extent are the climate history time series reliable in reality? To what extent does the double subjective 'filter' of the brain of the recording person and the brain of the researcher alter the original event? At this present stage I think three answers can be given to address this area of concern. First of all, we have to remain aware of the validity of this concern. Out of necessity, I often had to rely on very 'special' weather reports, and there are certainly far more sources of climate history in the archives than have been located so far. Subsequent inclusion of this additional data may have an altering effect on the conclusions related to climatic changes drawn from the present database. The second relevant fact is that the scale used for transforming the data into numbers is a deliberately limited one, thus minimizing the probability of this being a source of errors. And finally it is my opinion that the most important test of the time series in this study can be a comparison with a climate history time series created using other methods. Such a climate history reference could be the dendrological time series of *András Gryneaus* once it is complete, however at the present stage our climate history time series can only be compared to the instrument based time series from Budapest. The overlapping period between the temperature time series is of adequate length,

from 1780 through 1850. I compared the macro-regional time series to the Buda time series based on a correlation calculation, and the relation appeared strong in the case of every month. While the above indicates that the temperature time series is reasonably reliable, there is unfortunately no similar basis for a control comparison of the precipitation time series.

Table 2 *Correlation between the temperature time series based on instrument observations in Budapest and the temperature time series based on climate history for the country as a whole, between 1780 and 1850*

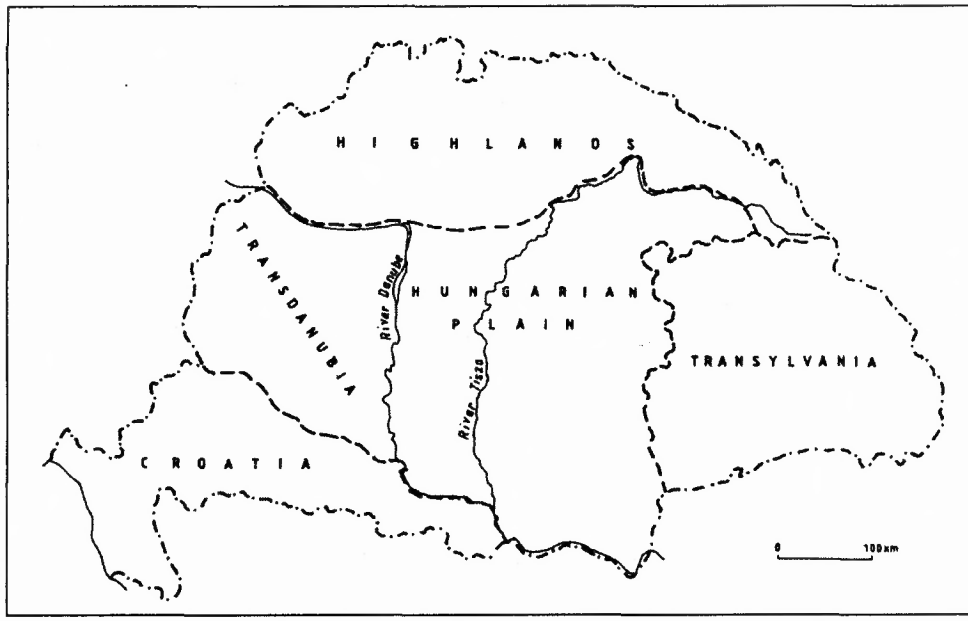
	0.727	0.617	0.394	0.519	0.534	0.644	0.624	0.595	0.452	0.392	0.547	0.698

Rácz, Lajos: Climate History of Hungary Since 16th Century: Past Present and Future.
Pécs: Centre for Regional Studies, 1999. 160 p.
Discussion Papers, No. 28.

3. CLIMATE CHARACTERISTICS OF THE CARPATHIAN BASIN

In my climate history analysis I use the temperature and precipitation time series of months, seasons, and of the whole year from the four macro-regions (Transdanubia, Highlands, Transylvania, Hungarian Plain) and the whole of the Carpathian Basin combining with the temperature and precipitation time series of Budapest. For purposes of analysis of the changes in climate, the category of standards has to be determined. Following the consensus of meteorologists I accepted the average of the period 1901-1960 as 'average', and my time series are compared to this value. To present the temperature and precipitation conditions of Hungary, I used the climate analysis of my former professor, *György Péczely* (1981).

Figure 9 *Macro-Regions of the Carpathian Basin: Transdanubia, Highlands, Transylvania and the Hungarian Plain*



3.1. Temperature Conditions of Hungary

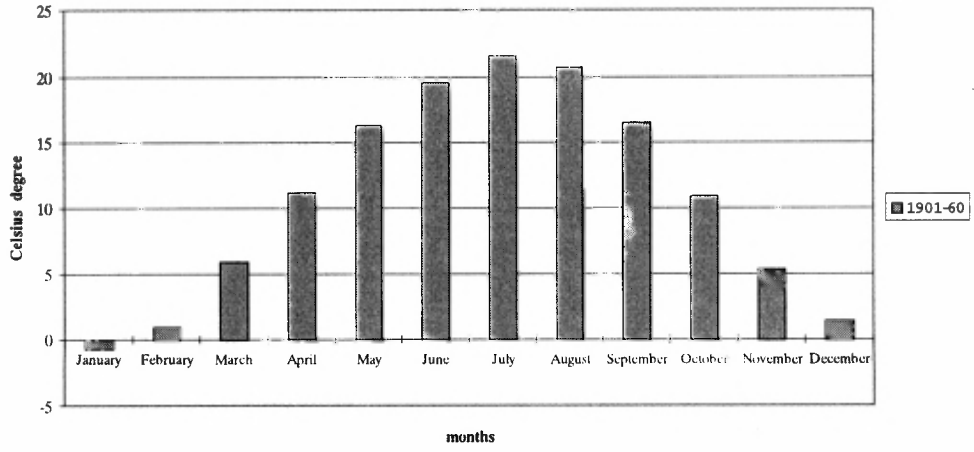
January is our coldest month, with the average temperature for the month falling as location moves from South to North and from West to East. The mildest region with

an average temperature over -1 °C is the Southwest, while the coldest region with an average temperature between –3 and -4 °C is the Northeast. This temperature distribution coincides well with the general isotherm system for January, and reflects the effects of the warm air masses from West-Southwest, and the cold ones from the Northeast. January and the winter temperatures in general show significant yearly differences. For example average temperatures in January have already been recorded in the –9 to -11 °C range, and also in the + 5-6 °C. The former corresponds to the expected average January temperature in Finland, while the latter resembles the mid-Winter temperature of the French and Italian Riviera.

The warmest month of the year is July, when the temperature falls as one moves from South to North, but goes up from West to East. So the coolest areas in the middle of summer are the northwestern and northern areas of the country, with an average temperature of 19 °C, while the hottest area is in the SouthEast with an average over 22 °C. This typical summer weather reflects the effects of the cool ocean air masses arriving from the Northwest and the warm continental ones from the Southeast. Temperatures recorded in July and the summer months in general do not reveal variations as significant as those of the winter months. The average temperature of our coolest July was between 17-18,5 °C, while those of the hottest July vary between 24-26 °C, reflecting a greater level of stability in summer weather patterns.

The course of temperature change in our country shows great stability with the monthly averages gradually increasing from January until July, and gradually decreasing from July until January.

Figure 10 *Monthly Average Temperatures in Budapest for the period 1901-1960*



The average annual temperature is highest in the Southern-South-Eastern parts of the country, around 11-11,5 °C, while the average in the North reaches only 8-9 °C, and in the higher mountains only 6-7 °C. In national terms, the average of about 10 °C seems to be adequate.

In order to interpret the sources used in tracing climate history, it is important to take into account the range of absolute maximum and minimum temperatures. The average of the greatest annual rise in temperature in Hungarian territory less than 200 m above sea level is 33-36 °C, while the average of the greatest decrease is 16-19 °C. In flat areas maximum temperatures exceeding 30 °C can be expected even in the coolest of summers and the absolute record high temperature in this region varies from 38-41 °C. During extreme summer heat the average temperature even at 1000 m above sea level can reach 30-31 °C. The most extreme cold expected in most parts of the country ranges from –25 to -30 °C, but in lower lying areas of the Plain and in mountain valleys the accumulation of cold air can lead to lows of -30 to -35 °C.

3.2. Precipitation in Hungary

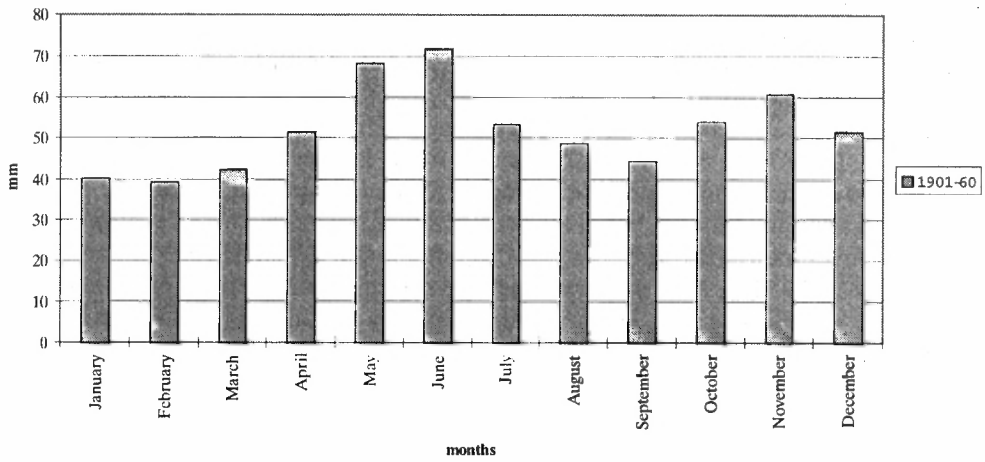
The territorial distribution of precipitation in Hungary shows significant differences, exceeding 900 mm in the Southwestern areas with the most rain, while the annual precipitation value in the middle area of the Plain is only 480-500 mm.

The country experiences the highest levels of precipitation in the May-July period, with the Western border-areas experiencing their highest rainfalls in July, while Transdanubia's highest rainfall occurs in May and the Plain experiences highest rainfalls in June. There is also an autumn (October-November), secondary period of high precipitation in the southern part of the country, which is the result of the Mediterranean climate. Lowest precipitation levels are experienced in the January-February period.

Yearly averages of precipitation vary a great deal. In the driest years precipitation on the Plain was limited to about 290-320 mm, while the averages in the rainiest Transdanubian areas reach as much as 1100-1400 mm. The distribution of precipitation varies significantly as well. As the long term precipitation time series show, a total lack of precipitation can occur in nearly any month, and hence precipitation levels of 200-300 mm can even occur during the six month summer season.

With the annual precipitation falling on average over 120-160 rainy days, rainfall can be expected on every third day of the year. The annual distribution of rainy days does not correspond to the precipitation distribution, as there is a higher concentration of rainy days at the end of autumn/beginning of winter, and a low concentration at the end of summer. This means that summer precipitation comes from less frequent but heavier rainfalls, while autumn-winter precipitation accumulates from more frequent, lighter rainfalls.

Figure 11 *Average Precipitation for Budapest from 1901-1960*



In our zone some of the precipitation falls in the form of snow. In lower areas of the country the average number of days with snow is 20-30, while it is about 50-60 in the higher mountains. Precipitation in the form of snow amounts to 50-100 mm on the Plain and Transdanubia, while it can even exceed 150 mm in some of the mountainous areas. About 10-15 percent of the annual precipitation in flat areas comes as snow, and 20-25 percent in the mountains.

When temperatures remain below zero, snowfall creates a snow-cover for some time. This snow-cover remains for the shortest time in the middle and south areas of the Plain, where the number of days with snow-cover is about 30-35. Despite a relatively milder winter, the greater portion of the Transdanubia has snow-cover for 40-50 days. The snow-cover remains for 100-120 days on mountains over 600-800 m. In the case of long and severe winters the Plains region can be covered with snow for 80-100 days, while the duration of the snow-cover in the higher mountains can last for as many as 140-160 days.

Rácz, Lajos: Climate History of Hungary Since 16th Century: Past Present and Future.
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4. CLIMATE VARIATIONS BY MONTH IN HUNGARY DURING THE LITTLE ICE AGE AND RECENT GLOBAL WARMING

To analyze the monthly climate changes I used the temperature and precipitation time series of the climate history indexes for the whole Carpathian Basin, correlating these to the time series of the instrument based measurements from the Budapest observatory. Three types of data were included in the analysis of the climate change trends. First the temperature and precipitation anomalies which were regarded as most significant for purposes of climate reconstruction were selected. Then the main points and trends of the 10-year average time series were described, and finally the course of climate changes over the centuries were discussed with the assistance of the 50-year average time series.

4.1. January

4.1.1. January Temperature Anomalies and Medium Term Trends

Temperature data from the 16th century is so sparse that no conclusion concerning the general climate-temperature trends can be drawn. The Bruckner Chronicle stated that the gardens burst into bloom from December 1538 to January **1539** owing to the mild weather (*Réthly*, 1962:70). *Sebestyén Borsos* also reported similar mild weather in Transylvania in January **1555** (*Réthly*, 1962:81; *Borsos*, 1855:17). In January **1560** *Istvánfi* wrote in his diary that the Hungarian military forces could easily cross over on the frozen ice of the River Tisza (*Réthly*, 1962:84; *Istvánfi*, 1867:443). January **1565** was again cold in the Highlands and on the Plain, as recorded by *Istvánfi*, stating that the rivers of both regions had thick ice cover (*Réthly*, 1962:84; *Istvánfi*, 1867:443). The cold weather of January **1567,** *Istvánfi* noted, caused a lot of grief for the royal troops in the Highlands (*Réthly*, 1962:89; *Istvánfi*, 1867:560). The series of cold January months in the years beginning in 1560 ended with a mild mid-winter in **1568**, as noted in *Zsigmond Torda*'s detailed records on the weather in the Highlands (*Réthly*, 1962:270).

The growing number of sources available from the last decade of the 16th century shows that most of the January months from the turn of the 17th century until the 1660s were especially cold. The first two decades of this fifty-year period saw the 15-year war between the Habsburg and Turkish Empire (1593-1606), and the war-related records include weather reports. The first record of a January anomaly were in *Istvánfi*'s diary, who wrote that in **1594** the royal troops in the Highlands found shelter from the January cold weather at the walls of the fortress in Košice (H-Kassa) (*Réthly*, 1962:104; *Istvánfi*, 1867:692). In **1601** the cold weather in January prevented the movement of military troops in Transylvania (*Réthly*, 1962:114; *Nagy Szabó*, 1855:65). In **1607** accord-

ing to *Máté Sepsi Laczkó* notes January was very mild in the Highlands (*Réthly*, 1962:124; *Sepsi Laczkó*,1857:115) Januarys of the 1640's remained very cold, but no special anomalies were reported. For two years in 1640s the midwinter was extremely cold, while Transylvania had a particularly cold January in **1641** (*Réthly*, 1962:163; *Haller*, 1862:67). Between these cold years in **1642** January was mild in Transylvania (*Réthly*, 1962:166; *Krauss*, 1862:136) *György Rákóczi II*, Prince of Transylvania reported in his letters of **1645** that the lower part of the Danube at South Plain froze (*Réthly*, 1962:173; *II. Rákóczi*, 1877:359). In the mid-16th century the war between the Emperor and the Sultan started again and in January **1656** the Turkish troops were able to cross the frozen Danube at Győr and massacre Christians (*Réthly*, 1962:184; *Speisser*, 1712:460). The series of cold Januarys in the first two thirds of the 17th century ended with the cold anomaly in **1669** when a nobleman from the Highlands reported that it was impossible to go hunting in January due to the very cold weather and deep snow cover (*Réthly*, 1962:290).

The decade of 1670s brought mild Januarys, then it became extremely cold at the turn of the 18th century. In January **1684** the Payr Chronicle recorded that the weather in Transdanubia was so cold that the water pipes in the houses and wine in the cellars froze, and the grapevines were damaged by the frost (*Réthly*, 1962:229; *Payr*, 1942:85). *Zsigmond Szaniszló* and *György Czegei Vass* also recorded similarly cold weather in Transylvania in January **1685** (*Réthly*, 1962:341). The temperature was especially low in January **1694** as noted by the different authors from the Highlands, Transylvania and from the Plain. The most interesting of these was probably the report by *Prince Imre Thököly* saying that the lower Danube at the South-Plain froze (*Réthly*, 1962:332). Doctor *Raygeri* noted in January **1697** that the Danube froze between Transdanubia and the Highlands and remained so for more than 8 weeks (*Réthly*, 1962:255; *Sydenham*, 1769:175). More than a decade later, in January **1709** the Fauth Chronicle marked a record in cold weather in Transdanubia from time beyond recall, wines and 'pálinka' (Hungarian brandy) froze in the casks while grapevines and walnut trees suffered frost damage (*Réthly*, 1970:46).

This trend of cold weather in January turned much milder in the 1720s and 1730s. In January **1727** *György Buchholtz* from the Highlands wrote that the weather was fairly mild and there was a constant wind from the South (*Réthly*, 1970:121; Nachrichten, 1727:30).

The coldest series of Januarys began in 1740 and lasted for 15 years according to my climate history based temperature time series, which shows that January **1740** in Transylvania was extremely cold, with strong winds. This weather even lead to some deaths (*Réthly*, 1970:157). Januarys of **1743** and **1745** also brought very cold weather to Transylvania (*Réthly*, 1970:168, 170; *Clauser*, 1937:230). The series of cold Januarys ended in January **1755**, when trees suffered frost damage during the severe Winter weather in Transylvania and mills were unable to grind due to the fact that even mountain streams froze (*Réthly*, 1970:191; *Bielz*, 1862:65).

The cold January weather lessened in the 1760's and 1770's. Thanks to the mild and rainy weather in January **1764** meadows were green (*Réthly*, 1970:211; *Cserei Gy.*,

1875:388). In **1771** the Historia Domus of the Franciscan Order in Gyöngyös reported a mild and rainy January (*Réthly*, 1970:474). The Calvinist pastor, *István Körtvélyesi Pap Junior* wrote in his diary that despite having some frost early in January **1772,** it quickly turned mild and the frost on the soil disappeared (*Réthly*, 1970:503).

The cold weather returned in the 1780's, the columnist of 'Pressburger Zeitung' in the Highlands wrote that most of the wells froze in January **1784** and there was a great shortage of water, with the daily minimum temperatures in settlements in higher regions dropping to -29,4 °C (*Réthly*, 1970:311; P.Z., 4th February). Similarly cold weather was registered at the Buda observatory on 5 and 7 January, both -21,3 °C. The Historia Domus of the Franciscan Order in Eger, however, reported in **1788** that January precipitation fell only in the form of rain (*Réthly*, 1970:513). The records from Transdanubia, the Highlands and the Plain also remarked on a cold January in **1799**, while the correspondent of 'Neuer Courir aus Ungarn' from the Plain reported that wine froze in the cellars, water-powered mine machinery did not operate, and wood became very expensive (*Réthly*, 1970:452; N.C.U., 29th January).

The historical sources from the first half of the 19th century reported on milder weather in January. This trend started in January **1804** when the article of 'Zipser Bote' noted from the Highlands that there was not any snow, only rain during the month (Réthly, 1998m:34; Z.B., 1879:2).

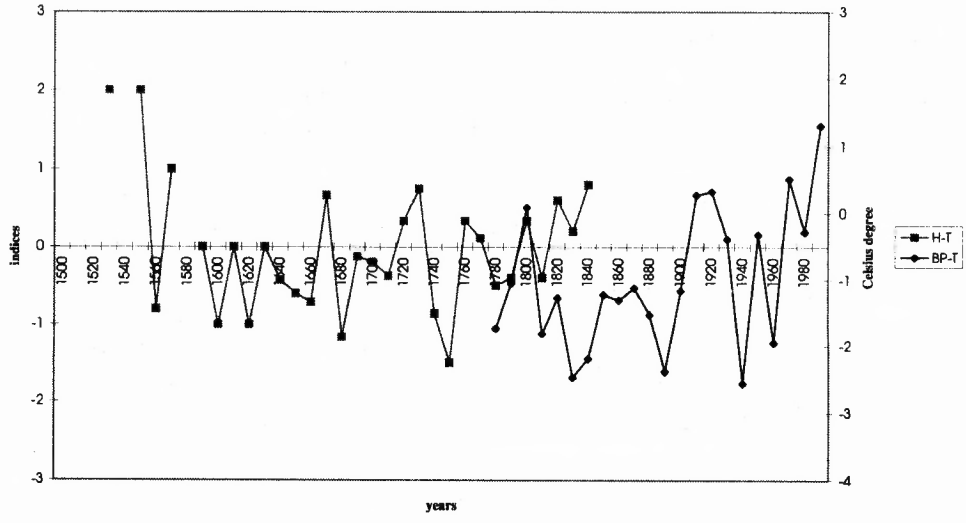
The series of this mild weather in the first half of the 19th century was interrupted only once at the beginning of 1810's. In January **1811** the correspondents from Transdanubia and the Plain reported in the column 'Hazai és Külföldi Tudósítások' (Local and Foreign Reports) that there was a thick ice cover on the Danube in January 1811 which allowed transportation on the river (*Réthly*, 1998m:95; H.K.T., 26th January). In January **1813** the Buda observatory registered temperatures as low as -22, -25 °C, and the correspondent of 'Pressburger Zeitung' from the Plain wrote that several shepherds died and the price of cattle dropped due to the shortage of coal (*Réthly*, 1998m:120; P.Z., 15th January).

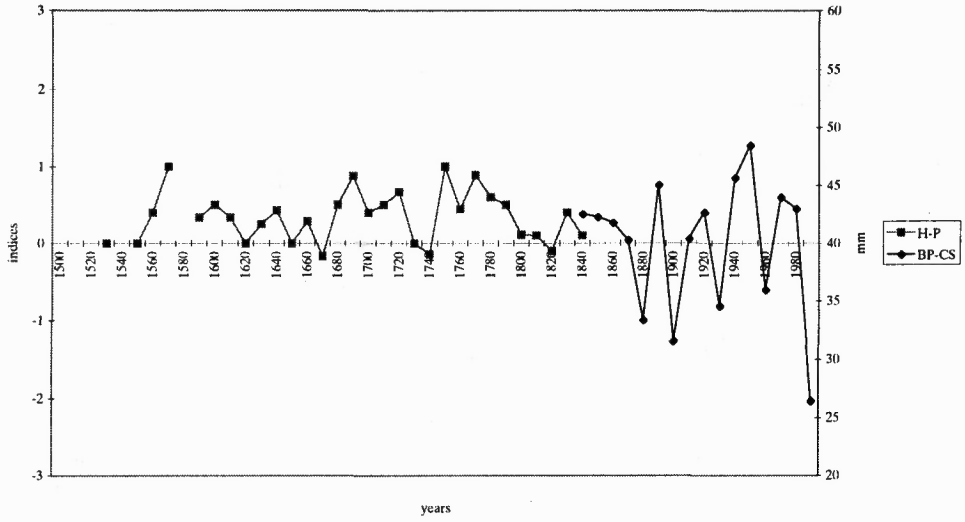
As of the 1820's mild average temperatures in January became dominant. In January **1822** the articles state that the weather was so mild that the grass turned green on the streets and in the city parks (*Réthly*, 1998m:311). January **1824** passed by with mild days, said the news from the Plain (*Réthly*, 1998m: 79). *Mihály Király*, Calvinist pastor in Transylvania wrote in his diary that weather in January **1825** was rather more like spring than winter (*Réthly*, 1998m:955). There was an exception in the middle of the winter of **1826** when the newspapers reported extremely cold weather. Minus 19 °C was registered in Buda on January 19th, and the Danube froze even between Pest and Buda (*Réthly*, 1998m:365; H.K.T., 21st January). The notes in the Historia Domus of the Franciscan Order in Jászberény related very cold weather in January **1830**, with temperatures as low as -27 °C registered at the monastery at the end of the month (*Réthly*, 1998m:421). Following a few cold Januarys the correspondent in Buda commented in January **1832** in the column 'Hazai és Külföldi Tudósítások' (Local and Foreign Reports) that the weather was spring-like, and the roads were muddy (*Réthly*, 1998m:459; H.K.T., 1st February). January **1833** in Transylvania – according to the news

in 'Hazai és Külföldi Tudósítások' (Local and Foreign Reports) – brought cold weather the likes of which had never been experienced before (*Réthly*, 1998m:468; H.K.T., 30th January). Whilst a year later, in January **1834** each region of the country enjoyed a rare 'heat'. In the register of a parish in Veszprém (Transdanubia) it was noted that the sour-cherry tree bloomed on January 22nd (*Réthly*, 1998m:481). The trend of mild Januarys continued in the 1840's, and *Mihály Király*, a Transylvanian pastor wrote that January **1843** was mild, windy and rainy (*Réthly*, 1998m:1017). The writers of 'Nemzeti Újság' (National Paper) also wrote about autumn-like mild weather in January **1845** and **1846** (*Réthly*, 1998m: 284, 287; N.Ú., 1st February, 1846). The last January anomaly in my climate history reconstruction occurs in **1848**, on the eve of the revolution, when the Pest-Buda correspondent for 'Nemzeti Újság' (National Paper) wrote that the Danube was frozen on January 13th through to the end of the month (*Réthly*, 1998m:705; N.Ú., 14th January).

An analysis of the mean temperatures by decade from the Budapest temperature time series reveals that the average January temperatures in the middle of the 19th century show a stable period of cold weather, while those for the last third of the century show a trend of warmer Januarys lasting into the first decades of the 20th century. In the middle third of the 20th century the weather dropped considerably twice, the first in the 1940's, and the second in the 1960's. Since the 1970's the average January temperature has shown a steady rising trend.

Figure 12 *January temperature and precipitation 10-year averages over the decades from the 16th century until today.*
The first diagram (1500-1850) is based on the time series of a history based climate reconstruction, while the second diagram is based on the time series for instrument observations from the Budapest observatory (1780-1996)





4.1.2. January Precipitation Anomalies and Medium Term Trends

It was not possible to get a general picture of the January precipitation rates of the 16th century due to scarcity of information sources available. These sources grew in number in the final decades of the 1500's and show that dry winters were rare in the Carpathian Basin, as were positive precipitation anomalies.

The first positive precipitation of January in my climate history records dates from **1607,** when *Máté Sepsi Laczkó* reported from Transylvania that the weather was rainy and cloudy (*Réthly*, 1962:124; *Sepsi Laczkó*, 1857:115).

After the surplus of precipitation during mild Januarys in the 17th century, the Januarys of the 1680's decade through the years of the 1720's turned not only cold, but also snow-covered, and the precipitation anomalies also grew. January **1684** was very snowy in Transylvania according to the diary of *Zsigmond Szaniszló* (*Réthly*, 1962:85). *György Czegei Vass* from Transylvania said that January of **1694** had an unusually high volume of snowfall (*Réthly*, 1962:348). The Payr chronicles from Sopron reported very cold days in Transdanubia in January **1697** with heavy snowfalls (*Réthly*, 1962:256; *Payr*, 1942:91), and *János Ádám Gensel*, a medical doctor in Sopron wrote that Transdanubia had a snow-cover of 9 feet (about 3 m) in January **1712** (*Réthly*, 1970:56; *Sydenham*, 1769:240).

After the years of the 1730's-1740's when there were balanced levels of January precipitation there was again a period of steady surplus precipitation in the second half of the 18th century. The first January precipitation anomaly worth mentioning of the half-century was registered in **1754** in the Bruckner Chronicles of Sopron according to which the regular January fairs could not take place due to the huge amount of snow in Transdanubia (*Réthly*, 1970:190). In **1771** the Historia Domus of the Franciscan

Monastery in Gyöngyös reported that there were serious spates in the Highlands following the uninterrupted periods of rain (*Réthly*, 1970:474). *István Körtvélyesi Pap Junior*, the Calvinist pastor of the Highlands indicated that January of **1774** was a wet one, but this time in the form of snow (*Réthly*, 1971:504). January of **1788,** according to the Historia Domus of the Franciscan Monastery in Eger was again very wet in the Highlands (*Réthly*, 1970:513).

In the first half of the 19th century January precipitation was balanced, with the first anomaly coming as late as January **1838** when a correspondent wrote in the 'Hazai és Külföldi Tudósítások' (Local and Foreign Reports) that the snowfall in Pest-Buda was so heavy that traffic in the city was nearly blocked (*Réthly*, 1998m:549; H.K.T., 17th January).

The continuous precipitation time series for January in Budapest starting in 1841 shows very unbalanced changes, with the middle of the 19th century exhibiting a stable precipitation level, followed by anomalies in opposing directions decade by decade. Of the January precipitation anomalies, the negative anomalies of the decades of the 1880's and 1900's deserve special attention, as do the positive ones in 1890's, 1940's and 1950's. Despite the major changes in the averages for various decades, there is a clear trend in the January months towards a higher rate of precipitation from the beginning of the 20th century.

4.1.3. January Climate Change Trends over the Centuries

Temperature

The high index for the first half of the 16th century is calculated based on one single figure, and therefore cannot be used for purposes of reconstructing climate history. The 50-year averages calculated on the basis of climate history time series show a prevalence of cold Januarys starting from the second half of the 16th century until the end of the 18th century. The coldest period of this cold era was in the 17th century and, following the period of temporary mild weather in the first half of the 18th century, the turn of the 19th century brought a stable trend of milder weather. The Budapest data prove that Januarys of the 19th century were equally cold, while the 50-year averages for Januarys started to gradually rise after the turn of the 20th century.

Precipitation

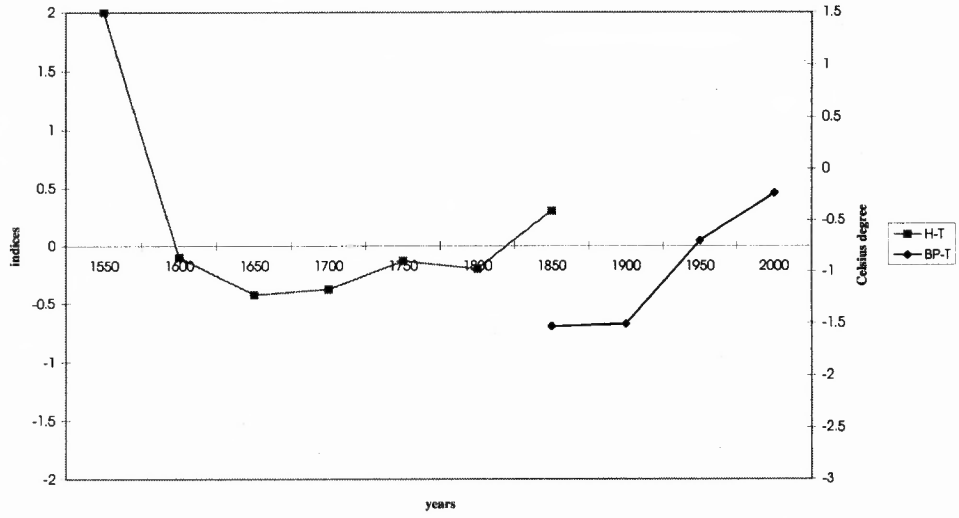
The 50-year average calculated from the January precipitation time series of my climate history reconstruction shows a slight, but stable precipitation for the duration of the three and a half centuries. There is little indication of fluctuation, with the first relative maximum precipitation dating from the first half of the 17th century, followed by some decreases until the mid-1700s, and a trend of Januarys with much higher precipitation rates again in the second half of the 18th century. The Budapest time series

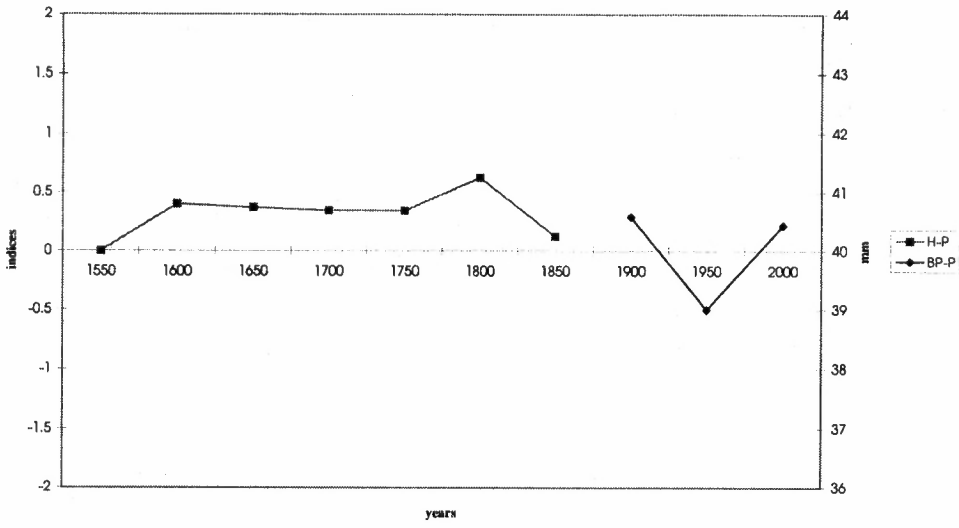
reveals a significant dry period starting in the first half of the 19th century that changed only in the 20th century.

Climatic Change Characteristics

The climatic history of the Little Ice Age with it's prevalence of cold, snowy Januarys lasted from the turn of the 17th century until the second half of the 19th century. The trend towards milder and drier weather in January goes back until the turn of the 19th century, but dry and mild weather appeared together in the first half of the 20th century. January temperatures continued to rise in the second half of the 20th century, while the trend towards lower precipitation rates stopped. During this period, January precipitation rates increased and often came in the form of rain or sleet due to the higher temperatures.

Figure 13 *January temperature and precipitation 50-year averages over the decades from the 16th century until today. The first diagram (1500-1850) is based on the time series of a history based climate reconstruction, while the second diagram is based on the time series for instrument observations from the Budapest observatory (1780-1996)*





4.2. February

4.2.1. February Temperature Anomalies and Medium Term Trends

There are no sources available from the first half of the 15th century concerning the weather changes in February. The first February-related data was noted by *Sebestyén Borsos* writing in his chronicle that February of **1555** brought very mild weather to Transylvania (*Réthly*, 1962:81; *Borsos*, 1855:17).

In the 1560s and 1570s the weather in February turned cold. In February **1565** the River Tisza had such a thick ice cover along the border between the Plain and the Highlands that even heavy guns could be transported on it (*Réthly*, 1962:87; *Istvánfi*, 1867:504). *Istvánfi* wrote in his chronicle in February **1567** that the royal troops suffered considerably from the cold weather in the Highlands (*Réthly*, 1962:89; *Istvánfi*, 1867:560). Turkish sources reported that in February **1575** *Pasha Mahmut* and his escorts arriving from Constantinople crossed the frozen Danube at the Town of Komárom on the border between Transdanubia and the Highlands (*Réthly*, 1962:92; *Takáts*, 1915:368).

The February temperature turned mild at the turn of the 17th century illustrated by a note in the Bruckner Chronicle that the trees turned green in February **1583** due to the mild weather (*Réthly*, 1962:97). It was also noted in the Bruckner Chronicle that forests in Transdanubia turned green again in **1607** (*Réthly*, 1962:125).

From the 1610s until the 1670s the February months were mostly cold and had stable average temperatures in the Carpathian Basin. Saxon chronicles indicate that

February **1652** was extremely cold in Transylvania (*Réthly*, 1962:180; *Krauss*, 1862:186). Chronicles from the Highlands reported that mid-winter in **1660** brought very severe weather (*Réthly*, 1962:189; *Szalárdi*, 1853:607).

The last two decades of the 17th century passed mainly with cold Februarys and with several temperature anomalies. This period of severe weather started in February **1684** when *Zsigmond Szaniszló* wrote from Transylvania that the cold weather caused deaths among both people and animals (*Réthly*, 1962:385). *György Czegei Vass* noted that February **1685** was not better than the year before (*Réthly*, 1962:341). *Zsigmond Szaniszló*'s chronicle showed that February **1689** was again extremely cold in Transylvania (*Réthly*, 1962:388). *Imre Thököly* wrote in his diary that mid-winter **1693** brought spring-like weather to the Plain (*Réthly*, 1962-325). The medical doctor *Raygeri* reported from Transdanubia that February **1697** (just like the whole winter) was extremely cold and the Danube had ice cover for a long time (*Réthly*, 1962:255; *Sydenham*, 1769:175).

The first decade of the 18th century shows an end to the series of predominantly cold years, with cold temperature anomalies balanced by mild midwinters. In February **1702** Doctor *Loew* reported from Transdanubia that the weather was very summer-like, with violets and waxflowers (Ceresorum acidorum) blossoming in the middle of the month (*Réthly*, 1970:30; *Sydenham*, 1769:297). According to *Loew*'s notes, mid-winter **1705** brought frosts to the Transdanubia (*Réthly*, 1970:36; *Sydenham*, 1769:312). February **1708** in the Highlands was mild but quite wet as well, and *Loew* wrote that flowers in Transdanubia blossomed that February as well (*Réthly*, 1970:42; *Sydenham*, 1769:334). Transylvanian records indicate that February **1709** brought very severe cold weather again (*Réthly*, 1970:84; *Cserei M.*, 1852:420). *János Ádám Gensel* commented that the weather in February **1713** was mild and rainy (*Réthly*, 197:60; *Sydenham*, 1769:243).

The beginning of the 18th century saw mainly fairly stable and less cold Februarys. According to the weather observations of *János Ádám Reimann* February **1725** brought very cold weather, and the same was noted in diaries from the Plain (*Réthly*, 1970:108-109; Sammlung, 1725:121). Information from the Highlands indicate that February **1740** brought a steady and long fall in temperature (*Réthly*, 1970:156; *Pálóczi-Horváth*, 1881:117). The diaries of this period reported that February **1763** was dry and warm in Transylvania (*Réthly*, 1970:203; *Halmágyi*, 1906:58), a year later, in February **1764** not only were the trees green in Transylvania, but planting had also begun (*Réthly*, 1970:211; *Cserei Gy.*, 1875:388). 'Pressburger Zeitung' wrote that the winter of **1776** passed with mild, rainy weather on the Plain (*Réthly*, 1970:246; P.Z., 24th February).

The months of February in the first half of the 19>th century were fairly mild with the number of warm anomalies exceeding that of cold ones. February **1806** in the Highlands was mild, rainy and foggy, and many people even started planting that month (*Réthly*, 1998m:52). The Pest-Buda correspondent wrote in 'Hazai és Külföldi Tudósítások' (Local and Foreign Reports) that the winter of **1816** ended with extremely cold weather, so that the Danube froze between Pest and Buda on the night of February 13 (*Réthly*, 1998m:224; H.K.T., 17th February). February **1817** in the Highlands had nice warm weather (*Réthly*, 1998m:253). The correspondents from the

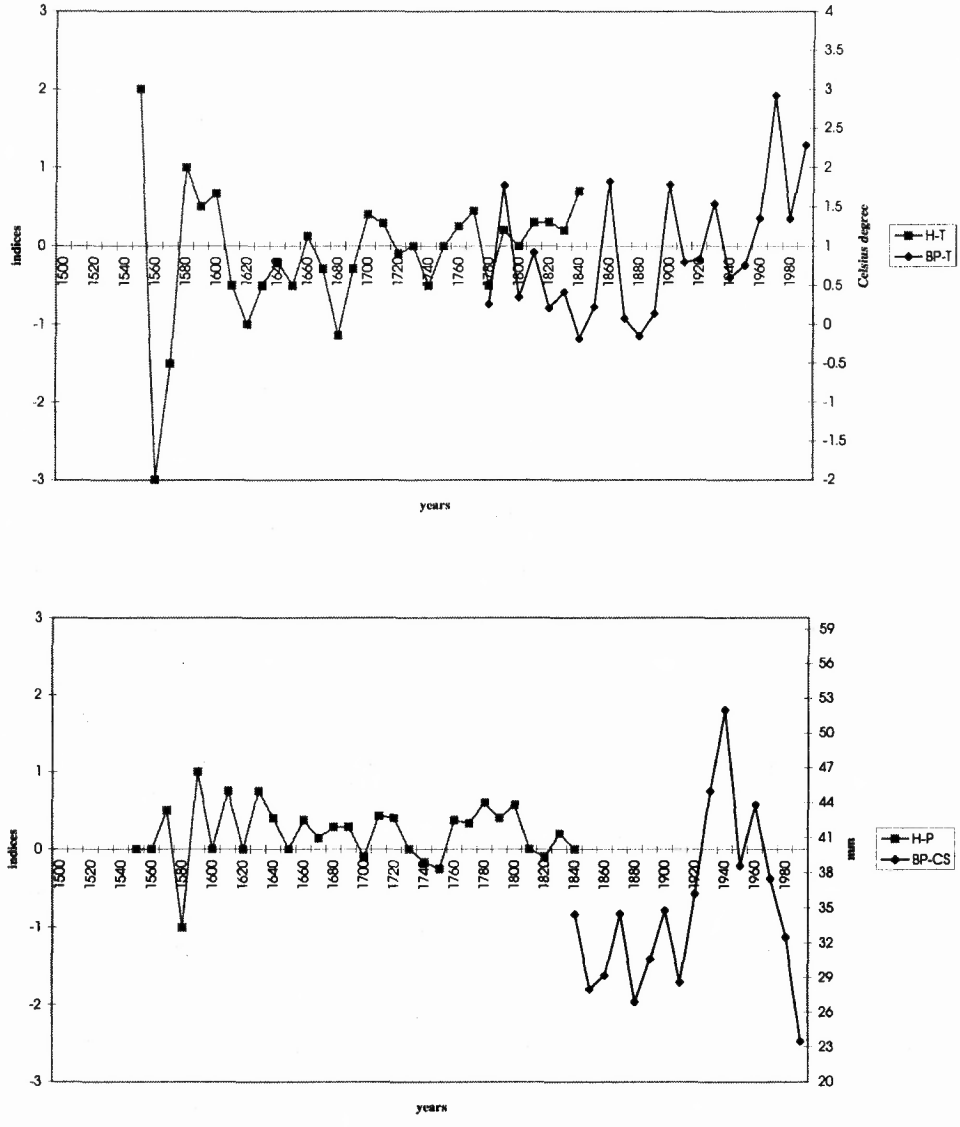
Highlands, Plain and Transdanubia reported in the 'Hazai és Külföldi Tudósítások' (Local and Foreign Reports) that there were only a few frosts at night at the end of the winter of **1818,** while the weather remained warm (*Réthly*, 1998m:260; H.K.T., 11th February). The Bruckner Chronicle informs us that the weather was so nice in February **1824,** that agricultural work could begin in the spring (*Réthly*, 1998m:347).

There were only two frosty Februarys worth mentioning in the first quarter of the 19th century, the first one in 1826, the second in 1830. It was written in the 'Hazai és Külföldi Tudósítások' (Local and Foreign Reports) that the temperature in Cluj (H-Kolozsvár) fell as low as -19 °C in February **1826** (*Réthly*, 1998m:366; H.K.T., 24th March) The Historia Domus by the Franciscan Monastery in Jászberény remarked that February **1830** brought extremely cold weather (*Réthly*, 1998m:422).

The series of mild Februarys continued from the mid-1830s. 'Pressburger Zeitung' published in February **1834** that the weather was so pleasant that vine-growers in Transdanubia started dressing the vine (*Réthly*, 1998m:482; P.Z., 26th February). An unknown diarist from the Plain wrote that late winter of **1835** brought mild weather while *Réthly* noted that it was muddy (*Réthly*, 1998m:1113). In **1843** an unknown diarist in Transdanubia also commented that February saw such mild, spring-like weather that trees blossomed and frogs were even heard croaking (*Réthly*, 1998m:643). The last anomaly of my February temperature time series is a positive one and dates from **1846.** *Gábor Ecsedy*, a Calvinist pastor in the Plain wrote that the winter ended with spring-like warm weather (*Réthly*, 1998m:1172).

The 10-year averages of the February temperature time series from Budapest show a cooling trend in the first half of the 19th century. Februarys of this century were rather cold, except for the very warm anomaly in the 1850s. A significant warming trend started in the 1890s and led to positive anomalies in the 1900s and 1930s. There were cool periods in the 1940s and 1950s, followed later from the 1960s onwards by a series of milder Februarys when large variations were observed.

Figure 14 *February temperature and precipitation 10-year averages over the decades from the 16th century until today. The first diagram (1500-1850) is based on the time series of a history based climate reconstruction, while the second diagram is based on the time series for instrument observations from the Budapest observatory (1780-1996)*



4.2.2. February Precipitation Anomalies and Medium Term Trends

Similarly to the temperature time series there are no information available on late winter precipitation from the first half of the 16th century. The first anomaly in my historical climatic reconstruction dates from February **1585** which passed with dry weather continuing into spring (*Réthly*, 1962:98-99; *Bielz*, 1862:21).

Starting from the 1590s, the February months remained rather wet for the next century, yet despite the constant precipitation surplus there are only two positive anomalies known to us. In **1594** *Istvánfi* wrote in his chronicle that the constant February rain and sleet restricted the movements of the royal troops in Transdanubia (*Réthly*, 1962:105; *Istvánfi*, 1867:694). According to Transylvanian news from February **1642** it rained every day and prevented movement of traffic on the roads (*Réthly*, 1962:166; *Haller*, 1862:76).

The weather in February at the turn of the 18th century became dry. By winter **1686** it got so dry that there were fires in the fields as reported by the Transylvanian *Zsigmond Szaniszló* (*Réthly*, 1962:387). An unknown diarist reported from the Plain, that there was neither snow, nor rain in February **1696** (*Réthly*, 1962:252). Doctor *Loew* recorded frost in February **1705** but there was no snowfall at all (*Réthly*, 1970:36; *Sydenham*, 1769:312) and he further noted that the series of dry Februarys ended in **1708** with a mild and rainy winter (*Réthly*, 1970:84).

February precipitation increased again in the 1710s, when *János Ádám Gensel* wrote that late winter **1713** brought constant 'warm rain' to Transdanubia starting on the 10th of February (*Réthly*, 1970:60; *Sydenham*, 1769:243).

These fairly wet decades led to a fairly dry period between the 1730s and 1750s with no remarkable anomalies.

Starting from mid-1760s the end of the winter saw a higher rate of precipitation and this trend continued until the first decade of the 19th century. The first anomaly of the 1760s was negative as February **1763** went by with dry and warm weather in Transylvania (*Réthly*, 1970:203; *Halmágyi*, 1906:58). *István Körtvélyesi Pap Junior*, a Calvinist pastor wrote in his diary in February **1765** that there were serious snowfalls at the beginning of the month, with precipitation late in the month falling as rain while the snow melted (*Réthly*, 1970:500). In February **1776** the 'Pressburger Zeitung' correspondent from the Plain reported that the month passed with mild weather, but there were long periods of rain (*Réthly*, 1970:246; P.Z., 24th February). *Sámuel Benkő*, a medical doctor in the Highlands wrote that in **1781** the month was cold with a lot of snowfall (*Réthly*, 1970:524), while the 'Pressburger Zeitung' correspondent reported that roads and settlements were in danger from foxes due to the thick snow cover (*Réthly*, 1970:279, P.Z., 7th February). The winter in **1804** ended in the Highlands with such significant snowfalls, people could not leave their homes until they made a tunnel (*Réthly*, 1998m:34).

Februarys in the first half of the 19th century were fairly stable and only one precipitation anomaly was recorded. The Pest-Buda correspondent reported an extremely dry

February in **1821** in 'Hazai és Külföldi Tudósítások' (Local and Foreign Reports) (*Réthly*, 1998m:296; H.K.T., 7th and 26th February).

The Budapest instrumental measurements showed that the weather in February in the second half of the 19th century was mostly dry, while the end of the winter was extremely dry in the 1850s, 1860s and 1880s. From the beginning of the 20th century February precipitation increased significantly, reaching peak levels in the 1930s and 1940s. Precipitation levels then began decreasing from the mid-20th century, which became quite noticeable in the 1960s.

4.2.3. February Climate Change Trends over the Centuries

Temperature

The February months from the second half of the 16th century until the end of the 17th century were somewhat colder than the average. The 50-year February temperature time series shows that February temperatures started to get milder during the first half of the 18th century, a trend that continues until today, and this process has speeded up especially in the 20th century.

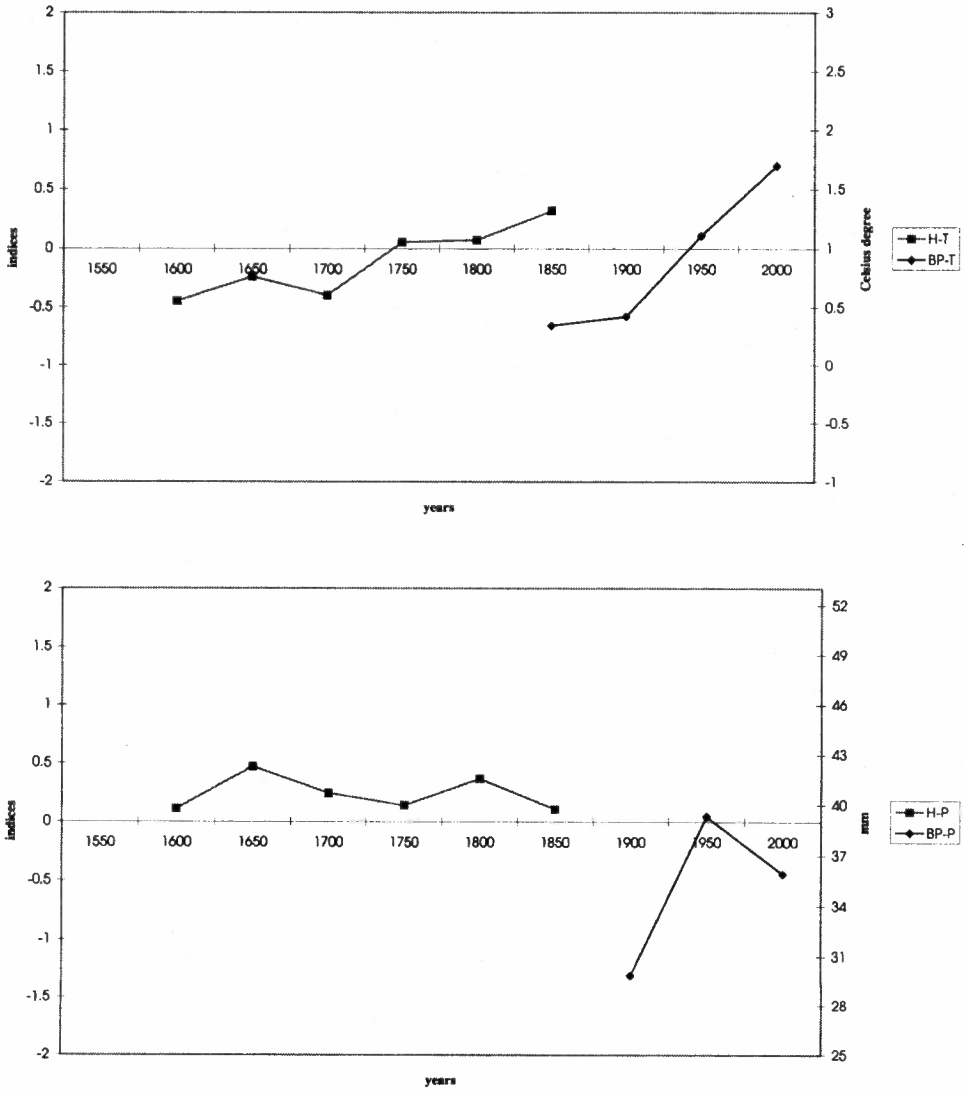
Precipitation

The 50-year averages calculated from the climate history precipitation index time series show a permanent February precipitation surplus, but to differing extents from the second half of the 16th until the middle of the 19th century. When graphed out, the February precipitation diagram shows two peaks, a stronger one in the first half of the 17th century, and a lesser one in the second half of the 18th century. The time series of reconstructed climate history and the Budapest instrument-based data show that February precipitation dropped significantly for a long period in the 19th century. Februarys in the first half of the 20th century apparently had higher precipitation levels followed by a slight drop in the second half of the century.

Climate Change Characteristics

The Februarys of the Little Ice Age were mostly cold and snowy beginning in the second half of the 16th through the end of the 17th century. While this slight wet trend continued through the 18th century and into the first half of the 19th century, Februarys turned milder. This trend of February months getting milder has remained notable until today, in conjunction first with a precipitation decrease in the 19th century, followed by a significant rise in precipitation in the first half of the 20th century and another precipitation drop in the second half of the century.

Figure 15 *February temperature and precipitation 50-year averages over the decades from the 16th century until today. The first diagram (1500-1850) is based on the time series of a history based climate reconstruction, while the second diagram is based on the time series for instrument observations from the Budapest observatory (1780-1996)*



4.3. March

4.3.1. March Temperature Anomalies and Medium Term Trends

The March months in the first part of the 16th century were fairly winter-like, in **1507** the Bruckner Chronicle wrote that the snow cover remained in Transdanubia also for March (*Réthly*, 1962:59). According to the Bruckner Chronicle, the long-lasting winter prevented the start of the spring agricultural work in March **1525** (*Réthly*, 1962:63). There were snowfalls in Transdanubia in the second half of March **1543** amidst cold weather (*Réthly*, 1962:73; *Kecseti*, 1859:84). *Zsigmond Torda* wrote in his diary that the beginning of spring in **1565** had cold but fine weather (*Réthly*, 1962:268).

No clear trend can be outlined from the sparse data originating at the turn of the 17th century. A study of the sources from the 17th century shows clearly that the months of March were mostly cold throughout the century, although negative temperature anomalies were recorded for the first time in the 1650s. In March **1651** the Payr Chronicle reported that the second half of the month was cold and snowy in Transdanubia (*Réthly*, 1962:180; *Payr*, 1942:38). A year later, in **1652** the Bruckner Chronicle reported that there was frost every day in March and agricultural work was delayed in Transdanubia as late as April (*Réthly*, 1962:181). Transdanubia had a cold, snowy and rainy early spring again in **1655** according to the Payr Chronicle (*Réthly*, 1962:184; *Payr*, 1942:47). *Ambrus Keczer* wrote in his diary in **1666** that the weather was wintry for the whole month of March in the Highlands (*Réthly*, 1962:286). March **1683** saw very wintry weather, wrote *Zsigmond Torda* (*Réthly*, 1962:384), the vegetation in Transylvania which had blossomed in the mild February weather, suffered a lot of frost damage in March (*Réthly*, 1962:226; *Hain D.*, 1853:22). The first warm March in the historical climate time series was recorded in March **1686** when early spring brought warm, fine weather to Transdanubia (*Réthly*, 1962:234; *Csányi*, 1858:122). Yet the mild March weather did not remain for the rest of the 17th century. Transylvanian records say that March **1691** was very cold, windy and rainy (*Réthly*, 1962:240; *Cserei M.*, 1893:151). *Raygeri*'s meteorological diary reported very cold winter in March in Transdanubia as well (*Réthly*, 1962:255; *Sydenham*, 1769:175).

By the beginning of the 18th century the cold March months were no longer so dominant, as indicated in the Fauth Chronicle in **1710** which describes an early spring in Transdanubia free of rain and with warm weather (*Réthly*, 1970:51).

Cold Marches again became dominant from the 1720s. In **1725** *György Buchholtz* reported from the Highlands that there were regular snowfalls and the ice on the streams was so thick ice that even vehicles could cross on it (*Réthly*, 1970:109; Sammlung, 1725:229-230). *György Buchholtz* observed that cool Marches were followed by a very mild early spring in **1728** in the Highlands (*Réthly*, 1970:127; Nachrichten, 1728:892). A Transylvanian pastor wrote in his diary in **1731** that the winter cold remained into the early days of April (*Réthly*, 1970:139; *Vásárhelyi*, 1948:145). March **1760** passed in Transylvania with such cold and windy weather that it prevented

the start of various agricultural works (*Réthly*, 1970:199; *Cserei Gy.*, 1875:358). According to the Historia Domus of the Franciscan Monastery in Gyöngyös, March **1763** brought very cold snowy weather to the Highlands, causing the death of many sheep, and vine-growers suffered considerable frost damages as well (*Réthly*, 1970:472). Reports from this period indicate that March **1767** passed with cold snowy weather in Transylvania (*Réthly*, 1970:224; *Cserei Gy.*, 1875:421), and a 'Pressburger Zeitung' correspondent reported from the Highlands that the torment caused by the early spring spates were coupled with very cold weather in **1768** (*Réthly*, 1970:227; P.Z., 9th March). *István Körtvélyesi Pap Junior*, Calvinist pastor in the Highlands wrote in his diary that the beginning of March was pleasant, but turned to winter again on the 12th of March (*Réthly*, 1970:503). According to *Körtvélyesi Junior*'s notes the year **1773** brought cold weather to the Highlands, while there were snow storms in the Plain causing the death of many animals (*Réthly*, 1970:235, 503). *István Körtvélyesi Pap Junior*'s diary reported about March **1775** that there was still plenty of snow that month (*Réthly*, 1970:504). The 'Pressburger Zeitung' correspondents from the Highlands and the Plain reported that the snow cover remained until the end of March **1784** and it was impossible to find fodder at any price (*Réthly*, 1970:314; P.Z., 20th and 27th March). The meteorological notes of *Sámuel Benkő*, a medical doctor in Miskolc, show that the average temperature in March **1800** was one degree lower than the February average (*Réthly*, 1970:464), and articles from the Plain reported that retailers left for the Pest fair in 'big snow' on the 19th of March (*Réthly*, 1970:464; *Magdics*, 1888:157).

March in the first two decades of the 19th century passed with fairly stable, cool weather, without any remarkable cold anomalies. Starting from the 1820s, early spring weather turned extremely cold again. Articles from the Plain state that early- and mid-March of **1820** brought severe frosts, and the weather turned pleasant by the end of the month (*Réthly*, 1998m:292). The correspondents from the Plain and Transdanubia wrote for 'Hazai és Külföldi Tudósítások' (Local and Foreign Reports) that the extremely cold weather of March **1824** caused death for both people and animals, while the frost froze the almond and peach-trees (*Réthly*, 1998m:340; H.K.T., 13th March and 3rd April). Particularly early, and mid-March of **1825** were winter-like, and a Pest columnist wrote in 'Hazai és Külföldi Tudósítások' (Local and Foreign Reports) that there were regular snowfalls until the middle of the month, with temperatures dropping as low as -10, -11,5 °C (*Réthly*, 1998m:353; H.K.T., 16th March).

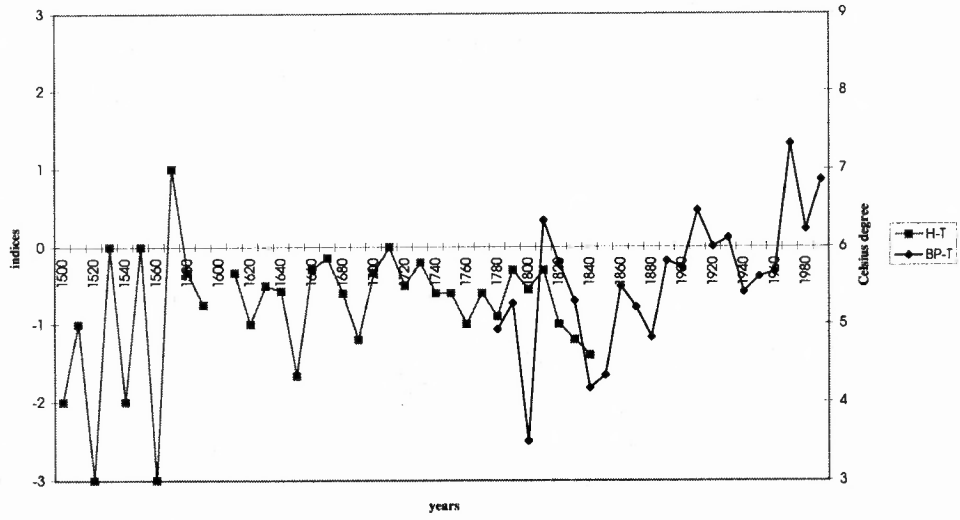
In **1830** the ice bridge between Buda and Pest remained on the Danube until the 19th of March (*Réthly*, 1998m:427; H.K.T., 31st March). *László Zlinszky* wrote from the Plain and *Mihály Király* from Transylvania that March **1834** passed with cold, frosty weather, and that there were several snowfalls in Transylvania, and going sleigh-riding was possible even at the end of the month (*Réthly*, 1998m:935, 980). *László Zlinszky* recorded in **1838** that the ice remained on the Danube until mid-March (*Réthly*, 1998m:937), while *Gábor Ecsedy*, Calvinist pastor wrote that it was snowing in the Plain also at the end of the month (*Réthly*, 1998m:1127). According to the correspondant of 'Hazai és Külföldi Tudósítások' (Local and Foreign Reports) March of **1839** were continuously cold and snowy in Transylvania (*Réthly*, 1998m: 577; H.K.T., 20th April). In **1840** the

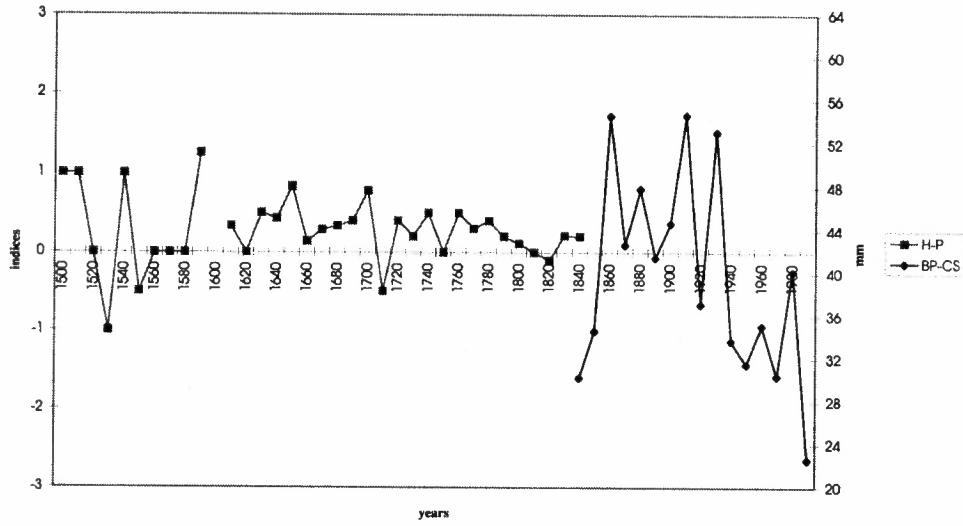
Historia Domus of the Franciscan Monastery in Mernye (Transdanubia) wrote that the mild winter was followed by such a cold March that it prevented the start of agricultural work, and the almond and peach crop was destroyed by frost (*Réthly*, 1998m:609).

Gábor Ecsedy, Calvinist pastor in the Plain noted that March **1843** passed with misty and frosty weather (*Réthly*, 1998m:1156). The early spring of **1845** was again remarkably cold and the 'Nemzeti Újság' (National Paper) reported that the ice on the Danube started to break up at Pest-Buda on the 21st of March and was still breaking up on the 30th (*Réthly*, 1998m:669; N.Ú., 23rd and 30th March). The first part of March **1847** was extremely cold and 'Nemzeti Újság' (National Paper) reported from the Highlands that there was still ice on the rivers in the middle of the month, and temperatures dropped as low as -10, -14 °C (*Réthly*, 1998m:695; N.Ú., 21st March). The correspondent from the Plain wrote for 'Pesti Napló' (Diary of Pest) that the Tisza River started to freeze up again owing to the extreme cold weather of March of **1850** (*Réthly*, 1998m:716; P.N., 29th March).

According to the average March temperatures of the Budapest time series over the centuries, early springs were cold in the middle of the 19th century, but a warming trend began in the mid-1800s and has continued until today. The first wave of March warming had its peak in the 1910s, followed by a slight cooling trend until the 1940s. The warming trend inevitably continued, with some variations, in the second half of the 20th century.

Figure 16 *March temperature and precipitation 10-year averages over the decades from the 16th century until today. The first diagram (1500-1850) is based on the time series of a history based climate reconstruction, while the second diagram is based on the time series for instrument observations from the Budapest observatory (1780-1996)*





4.3.2. March Precipitation Anomalies and Medium Term Trends

Regarding March precipitation, there is inadequate source material to reveal any trends for the 16th century. There are Saxon notes available stating that March **1580** was very dry in Transylvania (*Réthly*, 1962:96; *Hain D.*, 1853:10).

The first signs of early spring becoming wet date from the last decade of the 16th century, when *Istvánfi*'s Chronicle reported that in March **1594** there were constant rains and the roads, unfit for traffic due to the spates, prevented movement of the royal troops in the Highlands (*Réthly*, 1962:105; *Istvánfi*, 1867:697).

The March months were mostly wet from the beginning of the 17th century until the first decade of the 18th century. Despite the long-lasting prevalence of wet early springs, the first positive precipitation anomaly was recorded as late as the middle of the century. In **1655** the Payr Chronicle reported that March passed with sleet and rainstorms in Transdanubia (*Réthly*, 1962:184; *Payr*, 1942:47-49). March of the year **1664** left Transdanubia without any precipitation, noted the Payr Chronicle also (*Réthly*, 1962:200; *Payr*, 1942:61). *Count Mihály Teleki* wrote in a letter that in March **1675** it often rained and there were several sleet storms in both Transylvania and the Plain (*Réthly*, 1962:212; *Teleki*, 1905-26:VII.31). According to the Payr Chronicle, March **1676** deserved special mention due to the dry weather in Transdanubia (*Réthly*, 1962:216; *Payr*, 1942:74). *Andreas Loew*, a medical doctor in Sopron wrote in his meteorological diary that Transdanubia received a considerable amount of snow early in March **1707,** followed later in the month by frequent rain, causing the roads to become unfit for traffic (*Réthly*, 1970:41; *Sydenham*, 1769:323).

The series of mild but wet March months ended with a transitory period of dry early springs in the 1710s. The Fauth Chronicle reported in **1710** that March passed without

any precipitation falling in Transdanubia (*Réthly*, 1962:51). The early spring of **1715** was dry, without a drop of rain in Transdanubia, wrote the Fauth Chronicle (*Réthly*, 1972:62).

Similarly to the previous century, the fairly wet March weather became prevalent with a few anomalies starting from the 1720s until the end of the century. March **1767** went by with constant snow, sleet and rain storms in Transylvania (*Réthly*, 1970:224; *Halmágyi*, 1906:300). 'Magyar Hírmondó' (Hungarian Messenger) and 'Pressburger Zeitung'. correspondents reported early in the spring of **1782** that there were major snowstorms across the country at the beginning of the month, while in the second half there were rainfalls and spates unlike anything ever seen before (*Réthly*, 1970:292; M.H., 3rd April; P.Z., 3rd April). The series of the wet years ended with a dry March in **1794**, when 'Magyar Hírmondó' (Hungarian Messenger) reported from Transylvania that there was not a drop of rain and the soil totally dried out (*Réthly*, 1970:411; M.H., 2nd April).

According to documentary sources, precipitation in March was very balanced in the 19th century, with only two anomalies recorded both negative ones. In March **1823** the Pest-Buda columnist wrote in 'Hazai és Külföldi Tudósítások' (Local and Foreign Reports) that the dry weather prevented plowing (*Réthly*, 1998m:333; H.K.T., 5th April). Early spring in **1832** was so dry in the Plain and Transdanubia regions that clouds of dust were formed and the wind "carried dust" (*Réthly*, 1998m:459; H.K.T., 16th April).

Following some decades of dry weather in the 1800s, the second half of the 19th century and the first half of the 20th century were fairly wet. In this century we have experienced mostly wet March months but the averages over the century varied within broad limits with very wet March months of the 1860s, 1910s and 1930s, but early spring in 1890s and 1920s proved much drier. March in the second half of the 20th century became evidently much drier, and was extremely dry in the 1950s and 1970s.

4.3.3. March Climate Change Trends over the Centuries

Temperature

The diagram based on the 50-year averages of climate history reconstruction time series outlines two characteristics of the early spring climate change: on one hand the March months were mostly cold, but on the other hand, there were cyclic changes within this cold scale. The big negative anomaly in the first half of the 16th century is somewhat exaggerated and can be mainly attributed to the distorting effect of the very limited amount of sources data. The time series of the 50-year averages can be regarded as reflective of reality from the turn of the 17th century. One of the coldest periods of the climate history) temperature time series for March was the second half of the 17th century, followed by a more stable period in the first half of the 18th century. There was a continuing trend towards colder March months between the mid-18th and mid-

19th centuries. The Budapest temperature time series show that this pattern changed in the second half of the 19th century when a gradual warming trend started which continues until the present day.

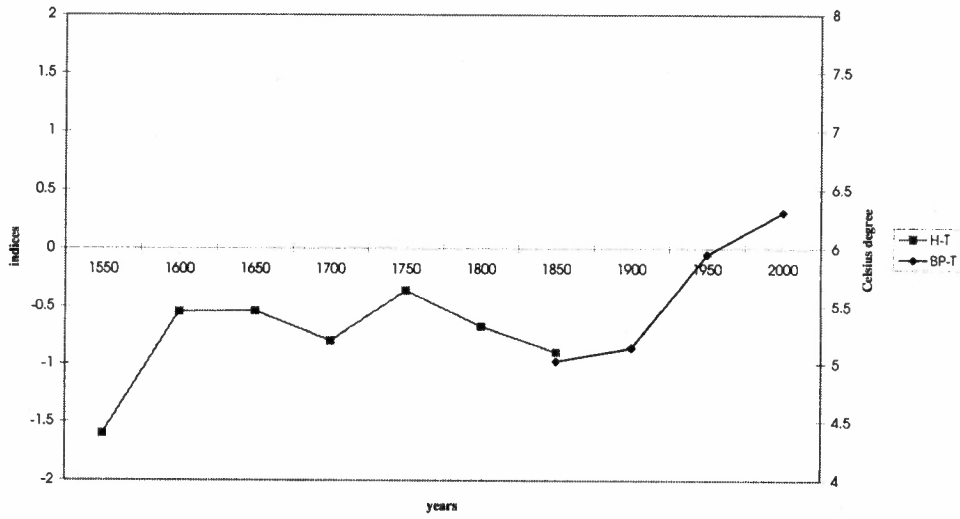
Precipitation

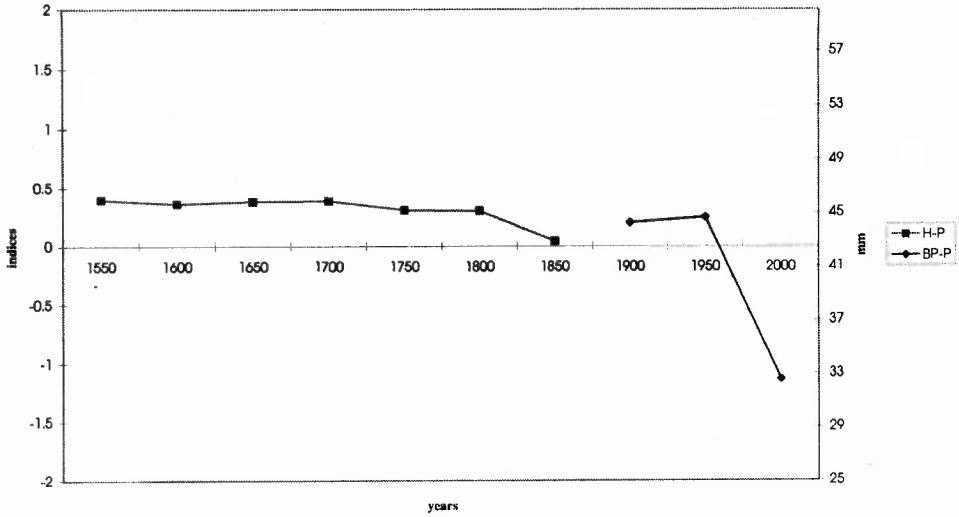
The 50-year precipitation averages calculated on the basis of the climate history time series show a long term but slight precipitation surplus. It is quite interesting that the time series shows a trend which started in the first half of the 16th century that, while extremely mild, was stable and it accelerated slightly in the first half of the 19th century. The Budapest precipitation time series show similar in the second half of the 19th century and in the first half of the 20th century. They became significantly drier from the mid-20th century onwards.

Climate Change Characteristics

The months of March in the Little Ice Age were mostly cold and fairly wet. The coldest and wettest period was in the second half of the 17th century, while early spring was far less wet during the significantly colder period of the 19th century. In the second half of the 19th century March started to turn warmer, while precipitation rates did not change significantly until the mid-20th century, with the second half of the 20th century bringing early warmer and drier springs.

Figure 17 *March temperature and precipitation 50-year averages over the decades from the 16th century until today. The first diagram (1500-1850) is based on the time series of a history based climate reconstruction, while the second diagram is based on the time series for instrument observations from the Budapest observatory (1780-1996)*





4.4. April

4.4.1. April Temperature Anomalies and Medium Term Trends

There are insufficient sources available from the 16th century to determine climate trends, but nevertheless two remarkable negative temperature anomalies were recorded. In **1507** the Bruckner Chronicle wrote that the winter lasted until the end of May in Transdanubia (*Réthly*, 1962:39). According to *Gáspár Hain*'s Chronicle from Levoèa (H-Lőcse), the weather turned cold in April **1534** and the snow caused serious damage to the trees in blossom and to the green crops (*Réthly*, 1962:68; *Hain G.*, 1910-13:69).

The April weather in the mid-16th century became very summer-like. In April **1540** the weather was very warm and dry for some time in Transylvania, which caused several forest-fires (*Réthly*, 1962:71; *Bielz*, 1862-63:70). After the eclipse of the 7th of April **1549,** the middle of the spring was hot and dry again, causing repeated forest fires in Transylvania (*Réthly*, 1962:76; *Bielz*, 1862-63:11). Transylvania had another unusually hot April in **1556** (*Réthly*, 1962:81; *Hain D.*, 1853-54:9). The series of warm Aprils ended with a cold spring in **1565**, when Transylvania suffered serious frost damages, *Zsigmond Torda* also wrote that the month was cold, wet and cloudy (*Réthly*, 1962:87, 268; *Bielz*, 1862-63:15).

At the turn of the 17th century, there were fairly cold mid-springs. A long-lasting climate change trend appeared in the 1640s, when the April weather became significantly colder, and this continued until the end of the century. *Count Mihály Teleki* wrote a letter from the Plain in April **1668** saying that it was snowing for weeks combined with blizzards (*Réthly*, 1962:205; *Teleki*, 1905-26:IV.289). In April **1676** *Gárpár Hain* record-

ed in his chronicle that there were significant snowfalls in the Highlands unlike anything ever seen before causing severe damages both in the fields, and forests causing the death of many forest animals (*Réthly*, 1962:215; *Hain G.*, 1910-13:446). *Raygeri* reported from the Highlands and *Zsigmond Szaniszló* from Transylvania in **1696** that April brought severe frosts (*Réthly*, 1962:252; *Sydenham*, 1769:174). In **1700** the whole of April brought frost and snow in Transdanubia, wrote *Andreas Loew* in his meteorological diary (*Réthly*, 1962:262).

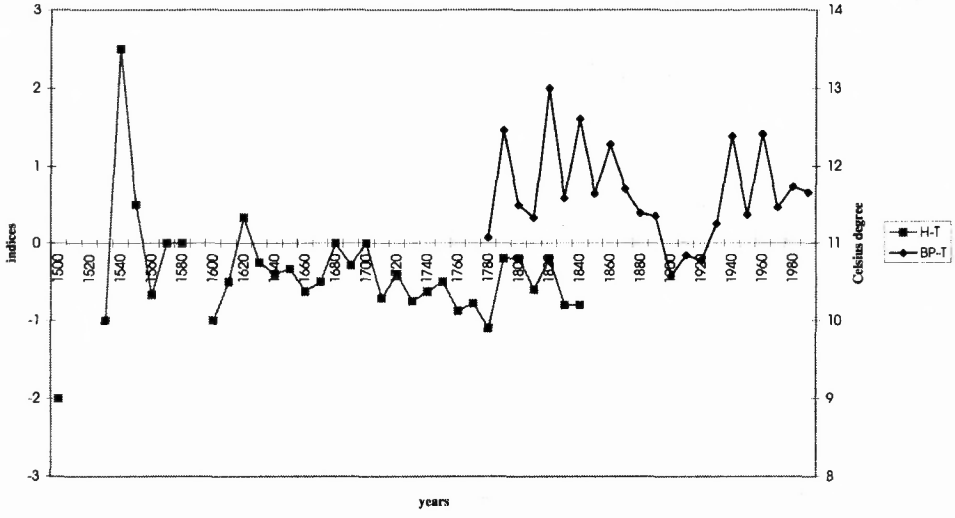
The beginning of the 18th century brought a renewed cooling trend that bottomed out in the 1780s, and ended around the end of the century. The first typically cold April was recorded in **1716**, when the Fauth Chronicle reported that the winter that year remained in Transdanubia until the end of April, and there was still not a single green tree in early May (*Réthly*, 1970:64-66). Transylvania had constant snowfalls in April of **1737**, which prevented the farmers from beginning their spring tasks (*Réthly*, 1970:148; *Apor*, 1863:199), and reports from the Plain said that trees had no green leaves at the beginning of May (*Réthly*, 1970:148; *Bielz*, 1862-63:62). The Transylvanian Saxon chronicles said that April of **1740** was cold in Transylvania (*Réthly*, 1970:158; *Károlyi*, 1866:V.169). On the other hand mid-spring was very warm in Transylvania in **1744**, as diaries from this period state that several fruit trees blossomed in the second half of the month (*Réthly*, 1970:171; *Apor*, 1863:235). Dry cold winds and scattered snowstorms followed each other in April **1759** (*Réthly*, 1970:197; *Cserei Gy.*, 1875:356). Both Transdanubia and Transylvania experienced an unusually cold mid-spring in **1764**, which caused a delay in the spring development of the vegetation (*Réthly*, 1970:213). There were extensive snowfalls in Transdanubia in March **1771**, the snow remained until April, and the spring planting could not start until early May (*Réthly*, 1970:232). Articles in both the 'Pressburger Zeitung' and the diary notes by Pastor *István Körtvélyesi Pap Junior* reported that the Highlands had a cold and snowy April in **1775**, and that winter weather prevailed practically until the end of the month (*Réthly*, 1970:242, 504; P.Z., 8th April). April **1784** was not only cold and snowy in the different regions of the country, but the frequent snowstorms caused deaths among people and animals (*Réthly*, 1970:315, 319-320; P.Z., 14th April).

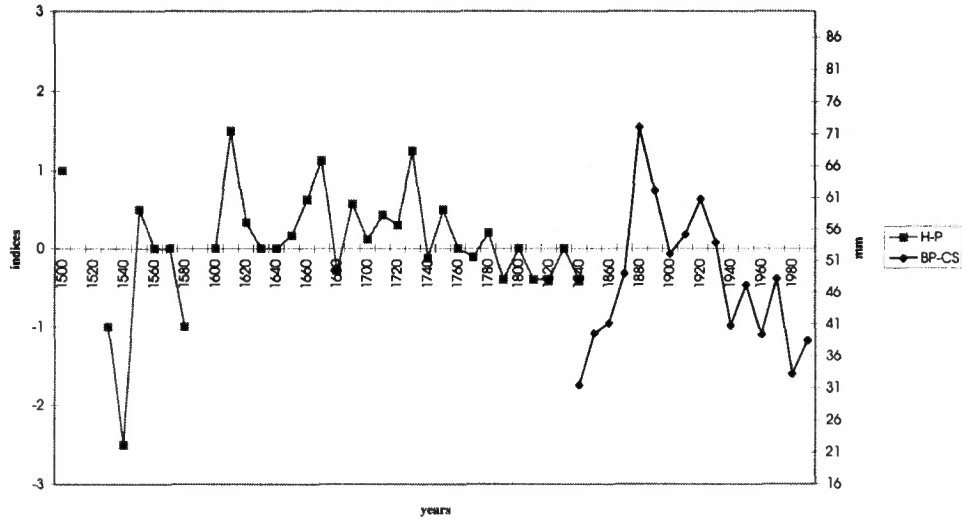
Following the transitory mild weather at the turn of the 19th century, it turned mostly cold again in mid-spring. The Historia Domus from the Franciscan Monastery in Eger wrote about cold weather in the Highlands in April **1802** (*Réthly*, 1998m:16). The correspondents wrote in 'Hazai és Külföldi Tudósítások' (Local and Foreign Reports) about snowfall in all regions of the country in April **1812** and the prevalence of cold weather costing the lives of many animals in the Plain (*Réthly*, 1998m:110-111; H.K.T., 29th April). In April **1823** an unknown diarist wrote about dry and cold weather in the Highlands, which greatly delayed the blossoming of the vegetation (*Réthly*, 1998m:338). The following year, **1824** brought similar weather to the Highlands in mid-spring when April was again frosty and dry (*Réthly*, 1998m:349). *Mihály Király*, a Transylvanian Calvinist pastor wrote in **1826** that April brought cold weather, frequent snow in mountainous regions, and frequent rain or sleet at lower elevations (*Réthly*, 1998m:958). There were reports of extremely cold weather and countrywide snowfalls

in April **1839** in 'Hazai és Külföldi Tudósítások' (Local and Foreign Reports) and 'Vereinigte Ofner und Pester Zeitung' (Réthly, 1998m:580; H.K.T., 10th April). Calvinist pastor *Mihály Király* wrote in his diary that April **1842** brought dry and cold weather to Transylvania which had negative effects on vegetation and there was a serious shortage of coal (*Réthly*, 1998m:1014).

According to the 10-year averages of the Budapest precipitation time series, Aprils in the first and second third of the 19th century were equally warm. Remarkably warm were the decades of the 1820s, 1840s and 1860s. The last third of the 19th century started a significant cooling trend, which continued also through the first third of the 20+>th century, with extremely cold April months for thirty years, from the beginning of the century until the end of the 1920s. Mid-spring became warmer again in the second half of the century with outstandingly warm weather in the 1940s and 1960s.

Figure 18 *April temperature and precipitation 10-year averages over the decades from the 16th century until today. The first diagram (1500-1850) is based on the time series of a history based climate reconstruction, while the second diagram is based on the time series for instrument observations from the Budapest observatory (1780-1996)*





4.4.2. April Precipitation Anomalies and Medium Term Trends

Those few sources available from the mid-16th century refer to very dry Aprils. The Highlands received not a single drop of rain in mid-spring **1532**, wrote *Gárpár Hain*, which resulted in a shortage of water and adequate grazing pasture for the herds (*Réthly*, 1962:67; *Hain G.*, 1910-13:53). Saxon sources from South-Transylvania wrote that April of **1540** was very hot and extremely dry, which caused wells to dry out and numerous forest-fires as well (*Réthly*, 1962:71; *Bielz*, 1862-63:70). Transylvania experienced another very dry April in **1549** when many rivers and wells dried up and there were forest-fires again (*Réthly*, 1962:76; *Bielz*, 1862-63:11).

The first third of the 17th century brought a very wet period, the most remarkable April precipitation anomaly of which came in **1614** when the Bruckner Chronicle wrote that it rained throughout the whole month of April in Transdanubia (*Réthly*, 1962:133).

Precipitation was balanced in the April months of the last 67 years of the 17th century, and only three anomalies are known of. April **1668** was remarkable not only due to its wet character, but because the most of the precipitation came in the form of snow to the Plain and Transdanubia as *Count Mihály Teleki* wrote in a letter (*Réthly*, 1962:205; *Teleki*, 1905-26:IV.289). *Gáspár Hain* from Levoča (H-Lőcse) recorded in his chronicle that there were extensive snowfalls in April **1676** unlike anything ever experienced before (*Réthly*, 1970:215; *Hain G.*, 1910-13:446). *Zsigmond Szaniszló* ended this run of wet Aprils in **1684** noting that the month passed with dry weather in Transylvania (*Réthly*, 1962:385).

The April months in the first third of the 18th century were mostly wet. *János Ádám Gensel* reported for 'Sammlung von Natur und Medicin...' that **1719** brought rainy and

snowy weather to the Transdanubia region (*Réthly*, 1970:80; Sammlung, 1719:673). Transylvania experienced a repeat of 'February' weather in April **1737**, as the month began with snow, later turning rather rainy (*Réthly*, 1970:148; *Apor*, 1863:199).

A trend towards drier Aprils began in the mid-18th century and continued until the mid-19th century. Transylvania saw not a drop of rain in April **1744** (*Réthly*, 1970:171; *Clauser*, 1937:230). Mid-spring was again dry in Transylvania in **1760** (*Réthly*, 1970:199; *Cserei Gy.*, 1875:358). In April **1781** 'Magyar Hírmondó' (Hungarian Messenger) reported that the crops in different areas of the Highlands did sprout due to the dry weather (*Réthly*, 1970:281; M.H., 19th May). The papers of that period wrote about a cross-country drought in April **1794** (*Réthly*, 1970:412; M.H., 2nd May). The Historia Domus of the Franciscan Monastery in Eger stated that April of **1802** was cold and dry in the Highlands and Plain (*Réthly*, 1998m:16). The year **1813** brought drought to the whole country again, wrote the 'Hazai és Külföldi Tudósítások' (Local and Foreign Reports) (*Réthly*, 1998m:123; H.K.T., 5th May). April **1825** passed by with dry and warm weather such that there was shortage of water in different areas of the Plain (Réthly, 1998m:354). *Mihály Király* recorded in April **1842** that it was dry and cold in Transylvania (Réthly, 1998m:1013).

According to the Budapest precipitation time series data, the April months in the mid-19th century were dry, but there was a significant trend towards higher rates of precipitation in the last third of the century that peaked twice, first in the 1880s and again in the 1920s. April months became much drier from the middle of the 20th century, and this trend accelerated, particularly after the 1970s.

4.4.3. April Climate Change Trends over the Centuries

Temperature

The time series of 50-year averages calculated on the basis of the climate history temperature indexes showed a stable and slight cooling trend from the mid-16th century until the second half of the 18th century. The extent of cold April weather in the first half of the 19th century decreased slightly. Based on the figures of the Budapest instrumental time series, the April weather became cooler again from the second half of the 19th century until the mid-20th century when a warming trend began which still prevails to this day.

Precipitation

The 50-year averages of the climate historical reconstruction time series reveal very interesting processes in the history of our climate. The diagram of the 50-year averages from the beginning of the 16th century until the mid-19th century describes a definite curve easy to follow, reflecting the highest levels of precipitation between the marked start and end point in the second half of the 17th century. An analysis of the diagram

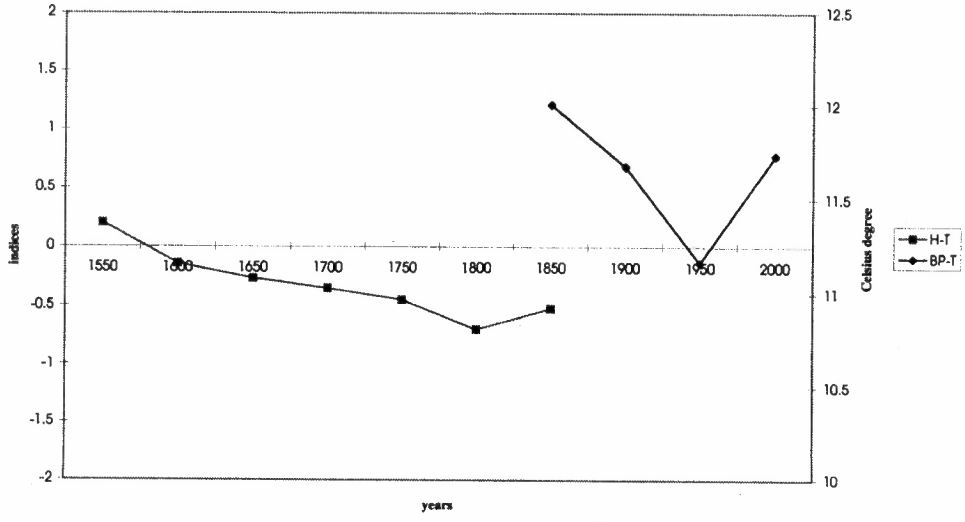
index values makes it apparent that the first half of the 16th century and that of the 19th century were rather dry. Wet Aprils, however, dominated from the turn of the 17th century until the end of the 18th century. The Budapest instrument-based records show that the levels of April precipitation remained constant from the mid-19th century until the mid-20th century with mid-springs in the second half of the century becoming drier.

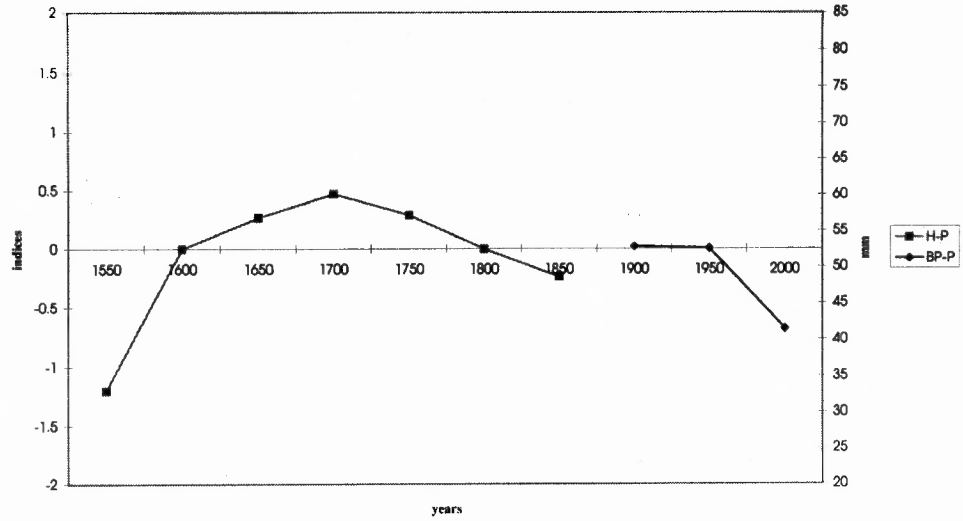
Climate Change Characteristics

Cold, rainy or snowy weather determined the April climate characteristics from the turn of the 17th century until the mid-18th century. The prevalence of cold Aprils continued in the second half of the 18th century and the first half of the 19th century, while becoming much drier

The figures of the Budapest instrumental time series show that Aprils became significantly colder with approximately constant precipitation levels between the second half of the 19th century and the first half of the 20th century. The April months with a warm and dry character became prevalent in the second half of the 20th century.

Figure 19 *April temperature and precipitation 50-year averages over the decades from the 16th century until today. The first diagram (1500-1850) is based on the time series of a history based climate reconstruction, while the second diagram is based on the time series for instrument observations from the Budapest observatory (1780-1996)*





4.5. May

4.5.1. May Temperature Anomalies and Medium Term Trends

Due to the scarcity of documented data, it is difficult to precisely determine the characteristic climate for the months of May in the 16th century, yet the available data points towards the conclusion that warm and often dry months dominated. The first documented May temperature anomaly dates from **1507** recording a cold and snowy late-spring (*Réthly*, 1962:59). **1541** brought very warm days in the late spring, with cherries already ripe in Transylvania around the middle of the month (*Réthly*, 1962:71; *Kemény*, 1893:185). In May **1551** the fields were dry in the Highlands due to a drought and unusual high temperatures (*Réthly*, 1962:78; *Wagner*, 1774:II.57). The late spring of **1585** was particularly warm and drought prevailed in Transylvania (*Réthly*, 1962:99; *Hain D.*, 1853-54:11).

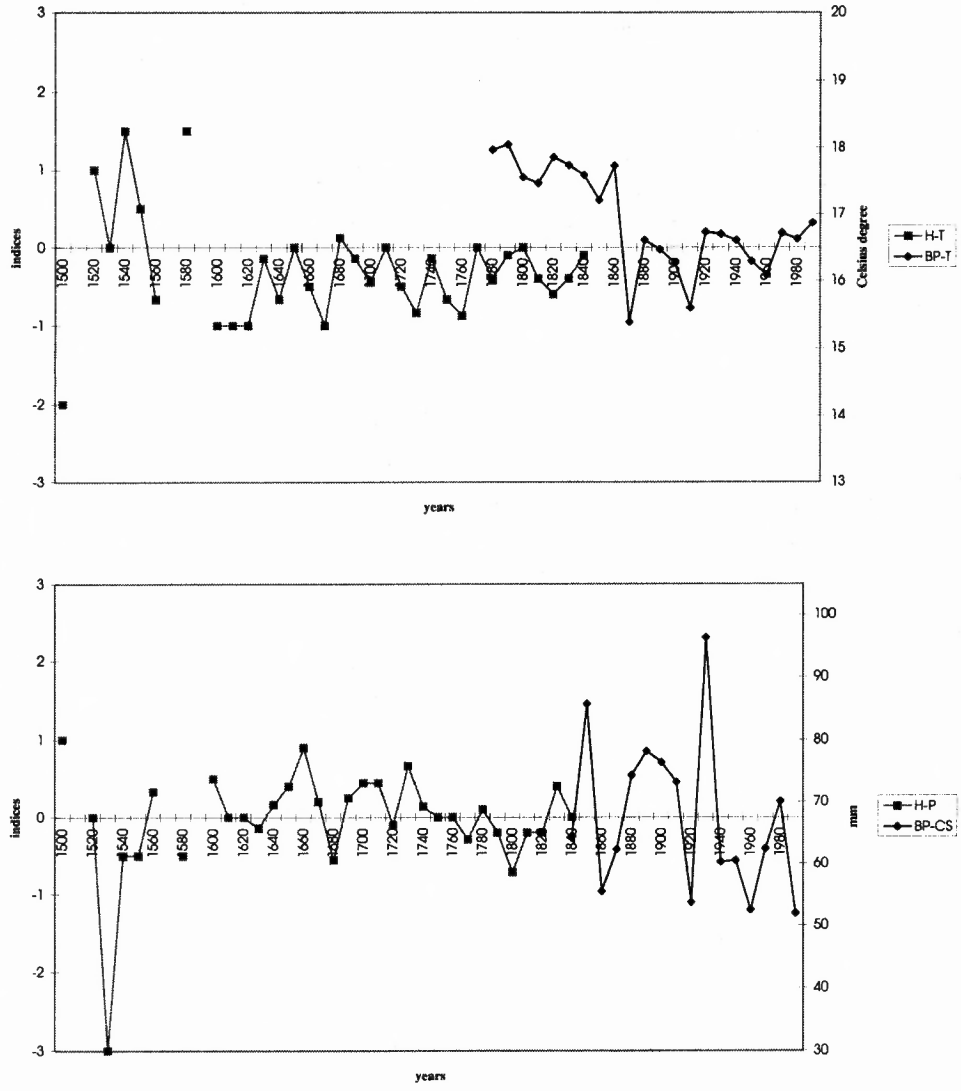
The May months of the 17th century were mostly cool, although there were a few cold anomalies. The Bruckner Chronicles reported May of **1635** to be cold and rainy in the Transdanubia region (*Réthly*, 1962:155). In **1642,** as described in the Payr Chronicle, cold weather in May continued on into early June in Transdanubia (*Réthly*, 1962:168; *Payr*, 1942:30). The Transdanubian Payr Chronicle indicated that May **1663** was 'hopelessly' cold (*Réthly*, 1962:198; *Payr*, 1942:57). The severe cold weather in May of **1675** caused loss of life among people and animals alike in the Highlands, wrote *Gáspár Hain*, and the spring planting suffered from frost damage as well (*Réthly*, 1962:213; *Hain G.*, 1910-13:434).

In the 1700s, the months of May were not much different than those of the previous century, being mostly cool despite some warm anomalies. According to *Andreas Loew*'s weather observations, warm and dry weather prevailed in Transdanubia in **1703** (*Réthly*, 1970:32; *Sydenham*, 1769:239). The first cold anomaly of the 18th century was recorded in May **1707** when *Andreas Loew* wrote in his meteorological diary that mainly cold, cloudy and rainy weather prevailed in Transdanubia (*Réthly*, 1970:41; *Sydenham*, 1769:323). In **1711** *János Ádám Gensel* reported it was unusually hot at the end of spring in the Highlands (*Réthly*, 1970:55; *Sydenham*, 239). The sudden cold and snow in May **1723** killed numerous fruit trees in Transylvania (*Réthly*, 1970:99; *Vásárhelyi*, 1948:143), and *György Buchholtz* noted that there was snowing and even blizzards at the end of May in the Highlands (*Réthly*, 1970:99; Sammlung, 1723:516). May **1726** was, on the other hand, hot and dry, also noted by *György Buchholtz* (*Réthly*, 1970:117; Sammlung, 1723:571). The next temperature anomaly recorded in May was in **1797** when *Sámuel Benkő* wrote that the weather of late spring was dry and the heat was stifling (*Réthly*, 1970:533).

The May months of the first half of the 19th century exhibited varying weather patterns. May **1826** passed with unpleasantly cool and rainy days, wrote the Pest-Buda correspondent for 'Hazai és Külföldi Tudósítások' (Local and Foreign Reports) (*Réthly*, 1998m:368; H.K.T., 31st May). The writers of 'Pressburger Zeitung' reported May of **1829** to be cold and rainy across the country (*Réthly*, 1998m:408; P.Z., 9th June). While in **1830** it was 'broiling hot', stated the 'Hazai és Külföldi Tudósítások' (Local and Foreign Reports) (*Réthly*, 1998m:438; H.K.T., 26th May). In **1833** May was very warm and dry again, and it was reported that crops in the Highlands suffered considerable damage due to the drought (*Réthly*, 1998m:470). The correspondents from the Plain and Highlands for 'Hazai és Külföldi Tudósítások' (Local and Foreign Reports) wrote that May of **1836** brought winter-like weather with regular frosts, and there was even a snowfall in the middle of the month, all of which caused serious damage to the spring crops, vineyards and fruit trees (*Réthly*, 1998m:512; H.K.T., 21st May).

A review of the mean temperatures by decade using the Budapest temperature time series show that the warm period of the first half of the 19th century was followed by cooler decades after the 1870s. From the second half of the 19th century until the present day the weather was cold in the decades of the 1910s and the 1960s, as it was in the 1870s as mentioned earlier, while the late spring was mild in the 1880s, 1920-40s and 1970-90s.

Figure 20 *May temperature and precipitation 10-year averages over the decades from the 16th century until today. The first diagram (1500-1850) is based on the time series of a history based climate reconstruction, while the second diagram is based on the time series for instrument observations from the Budapest observatory (1780-1996)*



4.5.2. May Precipitation Anomalies and Medium Term Trends

The few May months for which data exists from the 16th century were mainly remarkable for their dry character. In **1532** *Gáspár Hain* recorded in his notes that there was not a drop of rain in the Highlands for 12 weeks between the 24th of March and the 11th of June, the plants stopped growing due to the drought, and the herds had neither grass nor water (*Réthly*, 1962:67; *Hain G.*, 1910-13:53). There was drought again in the Highlands in May **1551,** scorching the spring crops and the grass (*Réthly*, 1962:78; *Wagner*, 1774:II.57). There is information in the record concerning the drought in Transylvania in **1585**, when dry weather from early May until the end of June stunted the growth of the corn crop, limiting it to a height of only one foot (32 cm) (*Réthly*, 1962:99; *Hain D.*, 1853-54:11; *Bielz*, 1862-63:20).

Precipitation in May during the 17th century was fairly balanced, with a slight precipitation surplus in the middle of the century, but only negative anomalies are found in the reference sources. Transylvania was ravaged by a drought in May of **1634** (*Réthly*, 1962:153; *Krauss*, 1862:117). A year later, in **1835** the Bruckner Chronicle reported a cold and rainy late spring in Transdanubia (*Réthly*, 1962:155). *György Dobronoki* wrote that the Highlands saw no rain at all in May of **1636,** causing wells and rivers to run dry, and in early June, the gravity of the situation was reflected by the fact that processions were held to ask for rain (*Réthly*, 1962:273). Transylvanian crops sown that spring suffered considerable damage due to the very dry weather in May **1640** (*Réthly*, 1962:162). *Gáspár Hain* wrote in his chronicle that settlements in the Highlands had to struggle with water shortages in May (and June) **1682,** as wells and streams went dry, rendering mills inoperable as well (*Réthly*, 1962:225; *Hain G.*, 1910-13:491).

The majority of the May months in the first half of the 18th century were wet, although there were a few exceptions. *György Buchholtz* wrote in **1700** that the weather in the Highlands remained rainy from Easter (Easter Monday was on April 11th) until September which caused serious damage to crops (*Réthly*, 1962:262). *Dr. Loew* also reported that Transdanubia had unpleasantly cold weather in May **1705** (*Réthly*, 1970:36; *Sydenham*, 1769:312). Two years later in **1707** the same period was cool again and unusually rainy, according to *Andreas Loew* (*Réthly*, 1970:41; *Sydenham*, 1769:323). *János Ádám Gensel* wrote that the country had flood-like spates in May **1712** due to the rainy weather (*Réthly*, 1970:57; *Sydenham*, 1769:241). May **1726** was dry in the Highlands, as noted by *János Ádám Reimann* (*Réthly*, 1970:117; Sammlung, 1726:534). *György Buchholtz* reported in the paper 'Nachrichten ...' published in Erfurt a report about a dry late spring in **1727** in the Highlands (*Réthly*, 1970:123; Nachrichten, 1727:297). It was also *György Buchholtz* who wrote about the weather in May **1735**, stating that there was a high volume of rainfall, with continuous precipitation over a six week period causing spates in the Highlands, washing away bridges, mills and houses (*Réthly*, 1970:145). The Bruckner Chronicle reported a very rainy May in Transdanubia in **1745** (*Réthly*, 1970:174).

The late-spring weather turned much drier in the second half of the 18th century, becoming most remarkable in the first decade of the 19th century. Transylvania experi-

enced a cool and dry May in **1760**, when recently sown crops again suffered considerable damage due to the drought conditions (*Réthly*, 1970:199; *Cserei Gy.*, 1875:358), while the same month in **1797** was very hot and dry in the Highlands, wrote *Sámuel Benkő* in his meteorological notes (*Réthly*, 1970:533). According to the Historia Domus of the Franciscan Monastery in Kecskemét, the month of May in the year **1807** was very dry on the Plain (*Réthly*, 1998m:55). A year later, in **1808** the 'Hazai és Külföldi Tudósítások' (Local and Foreign Reports) stated that the plants in the fields of the Plain did not exhibit any growth due to the drought conditions late that Spring (*Réthly*, 1998m:63; H.K.T., 1st June). May of **1811** was warm and dry in the Highlands (*Réthly*, 1998m:103). Father *István Debreczeni*, a Calvinist pastor noted in his diary that the weather in the Plain was very dry in **1822** (*Réthly*, 1998m:876), while three years later, in May **1825** it became so dry that there was a shortage of water in several areas of the Plain (*Réthly*, 1998m:353).

Late spring precipitation in the second quarter of the 19th century was more balanced, with anomalies of both extremes. The Pest-Buda correspondent for 'Hazai és Külföldi Tudósítások' (Local and Foreign Reports) wrote that May **1826** brought mainly cool, unpleasant weather along with constant rains (*Réthly*, 1998m:368; H.K.T., 31st May). The correspondent from the Highlands for 'Pressburger Zeitung' reported a cold and rainy May in **1829** (*Réthly*, 1998m:408; P.Z., 9th June), while in **1833** the 'Hazai és Külföldi Tudósítások' (Local and Foreign Reports) stated that there was not a drop of rain, so the recently sown crops could not grow (*Réthly*, 1998m:470; H.K.T., 26th May). Various papers of the period reported that constant rains and extensive floods hit the country in May **1837** (*Réthly*, 1998m:541; E.H., 6th June; H.K.T., 7th June). 'Hazai és Külföldi Tudósítások' (Local and Foreign Reports) published a report stating that each region of the country suffered from spates in the late spring of **1839** as a result of constant rains, and witches were accused of causing the calamities (*Réthly*, 1998m:582; H.K.T., 3rd July). *Mihály Király*, a Calvinist pastor wrote that Transylvania experienced a very dry May in **1841** and the drought was such that it limited plant growth (*Réthly*, 1998m:981). The correspondents of 'Nemzeti Újság' (National Paper) reported that May **1845** was very rainy across the country, with floodwaters covering agricultural fields over a very large area (*Réthly*, 1998m:671; N.Ú. 3rd June). The year **1846** brought very dry weather to Transylvania, reported the 'Erdélyi Hírmondó' (Transylvania Messenger) (*Réthly*, 1998m:684; E.H., 11th June).

A review of the mean precipitation rates (by decade) as represented by the Budapest precipitation time series for May reveals a very unstable distribution. Ranges of fluctuation reach as high as 40 mm, which is quite remarkable when one takes into account the fact that the precipitation average for May was 68 mm. The extreme values of the May temperature 'curve' can be summarized as follows: wet 1850s, dry 1860s, wet 1890s, dry 1920s, very wet 1930s, dry 1960s, and moderately wet 1980s.

4.5.3. May Climate Change Trends over the Centuries

Temperature

A review of the 50-year temperature averages reveals that the months of May in the 16th century were mostly mild, but there was a significant cooling trend in the first half of the 17th century. Mays continued to remain cool in the second half of the 17th century, but not so cool as in the first half. This characteristic of slightly cool May months continued until the mid-19th century. The 50-year May temperature averages calculated using time series produced from the Budapest instrument observation data show a cooling trend from the mid-19th century until the mid-20th century when the situation reversed and in the second half of our century a slight warming trend has prevailed.

Precipitation

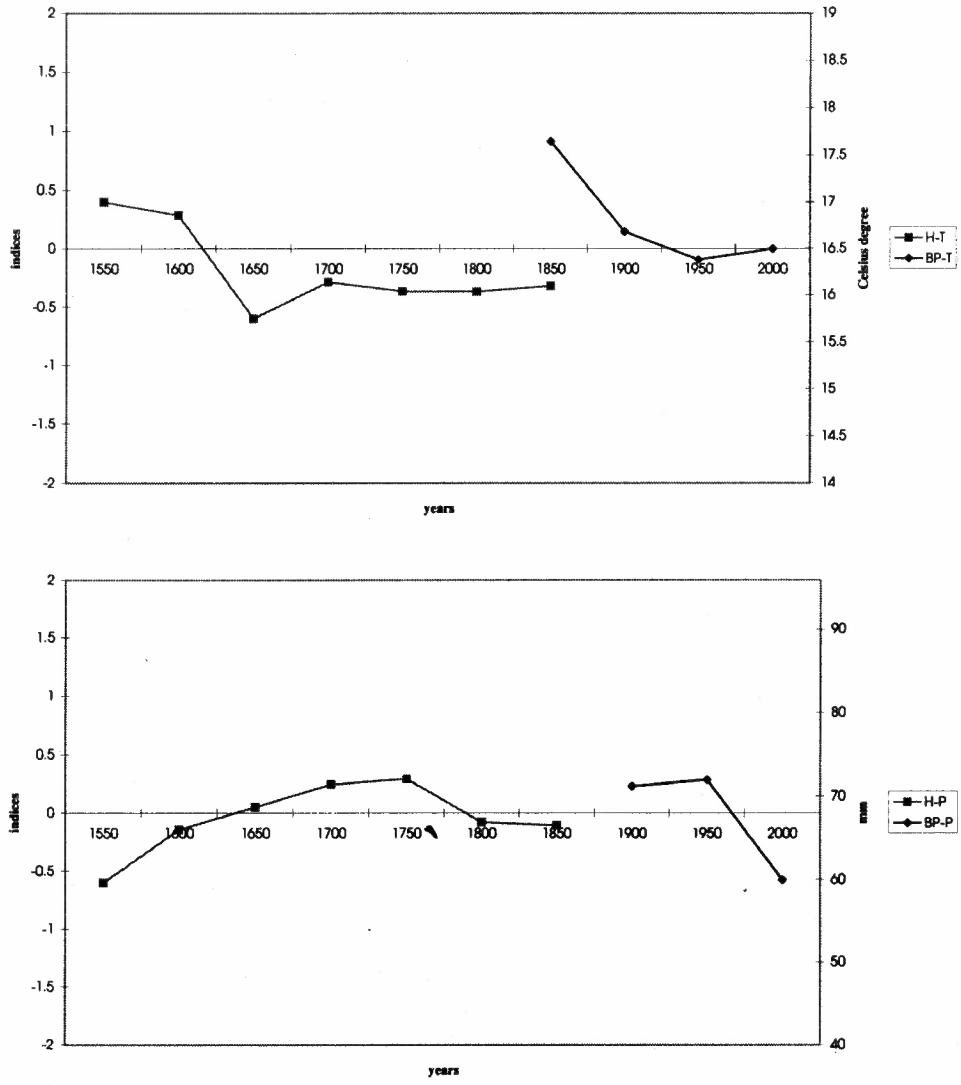
A graph based on the 50-year precipitation averages for May calculated using historical climate reconstruction methods is largely similar to that for April, but the duration and the volume of the precipitation surplus in May is significantly less than that of April. May weather was slightly dry until the mid-17th century, turning wet in the second half of the 17th century and even more so in the first half of the 18th century. Precipitation in the late spring during the second half of the 18th century and the first half of the 19th century was balanced. The 50-year average calculations based on precipitation time series from Budapest instrument-based observations show that the precipitation distribution remained balanced from the mid-19th century until the 20th century. In the second half of the 20th century there is a significant trend towards dry weather.

Climate Change Characteristics

An assumption based on the sparse data available, and partly in spite of that fact, is that the months of May were mostly warm and dry in the 16th century, while they turned rather cool and wet from the beginning of the 17th century until the mid-18th century. This characteristic cool climate prevailed until the mid-19th century, while late spring precipitation was fairly balanced throughout the period.

The time series derived from the instrument-based observations in Budapest show that May temperatures and precipitation rates varied in opposition to one another. During the period of decreased temperatures lasting until the middle of the 20th century, precipitation rates increased slightly, and when temperatures moderated in the second half of our century, precipitation rates decreased to produce a significant dry trend.

Figure 21 *May temperature and precipitation 50-year averages over the decades from the 16th century until today. The first diagram (1500-1850) is based on the time series of a history based climate reconstruction, while the second diagram is based on the time series for instrument observations from the Budapest observatory (1780-1996)*



4.6. June

4.6.1. June Temperature Anomalies and Medium Term Trends

Based on the meager quantity of records available, it is to be presumed that the months of June in the middle and the second half of the 16th century were mostly warm. There were two positive anomalies entered in the records. June was extremely warm and dry in **1551** according to the records from the Highlands (*Réthly*, 1962:78; *Wagner*, 1774:II.57), while Transylvania had a hot and dry early summer in **1585** (*Réthly*, 1962:99; *Hain D.*, 1853-54:11). The sequence of warm Junes was interrupted in the year **1606** with cold weather unlike anything previously experienced. It even snowed in Transylvania and the sudden frosts damaged corn, recently planted crops, and trees in both gardens and forests (*Réthly*, 1962:123; *Bethlen F.*, 1782-93:VI.465; *Bielz*, 1862-63:32).

June months exhibiting extreme temperatures were very rare in the 17th century, apart from the cold anomaly recorded in 1606 referred to above, we have knowledge of only one other anomaly in this season. Both the Bruckner and Payr Chronicles reported that June of **1619** was hot and dry in Transdanubia (*Réthly*, 1962:140; *Payr*, 1942:14).

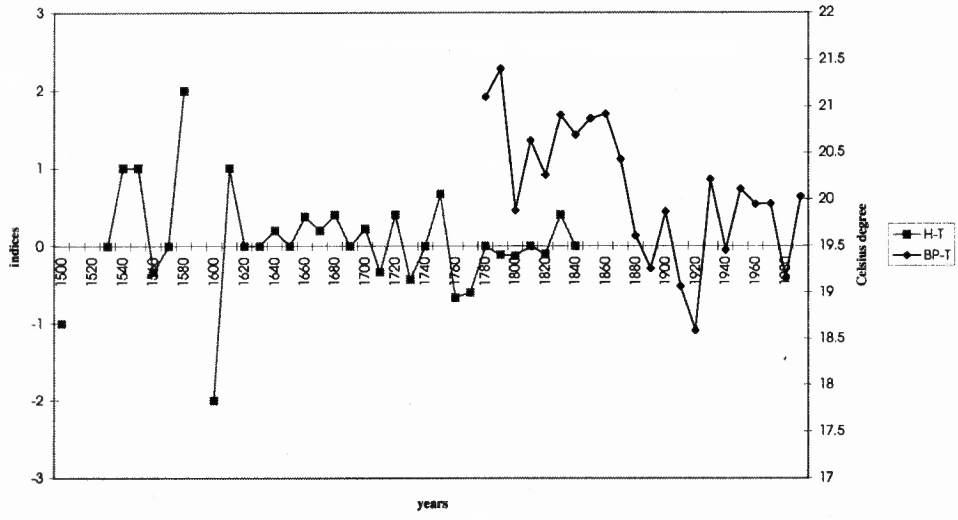
The temperature averages of the 18th century show balanced temperatures in June, although that century saw several early summers with extreme weather. Positive temperature anomalies were recorded rather in the first half, while negative ones appear mainly in the second half of the 18th century. *Andreas Loew* wrote in his diary that in June of **1703** it was so warm that the vine-blossoms were gone in Transdanubia by the middle of the month (*Réthly*, 1970:32; *Sydenham*, 1769:299). *Dr. Loew* reported another very hot early summer four years later in **1707** in Transdanubia (*Réthly*, 1970:41; *Sydenham*, 1769:323). Transylvania experienced extremely dry weather in June of **1710** (*Réthly*, 1970:51; *Cserei M.*,1852:441). The sequence of hot June months continued in Transdanubia in **1712**, and again *Andreas Loew* recorded the extreme heat (*Réthly*, 1970:57; *Sydenham*, 1769:242). According to the meteorological records of *István Pál Bácsmegyei*, extremely hot and dry weather prevailed in the Highlands in June of **1726** (*Réthly*, 1970:117; Sammlung, 1726:702). Diaries from **1755** reflect that grazing land in Transylvania was scorched due to the June heat and drought (*Réthly*, 1970:192; *Vásárhelyi*, 1948:236). In Transylvania in **1767** June was as cold as November (*Réthly*, 1970:225; *Cserei Gy.*, 1875:421). Father *István Körtvélyesi Jr.* reported in his diary that June weather in **1777** was cold and rainy (*Réthly*, 1970:505).

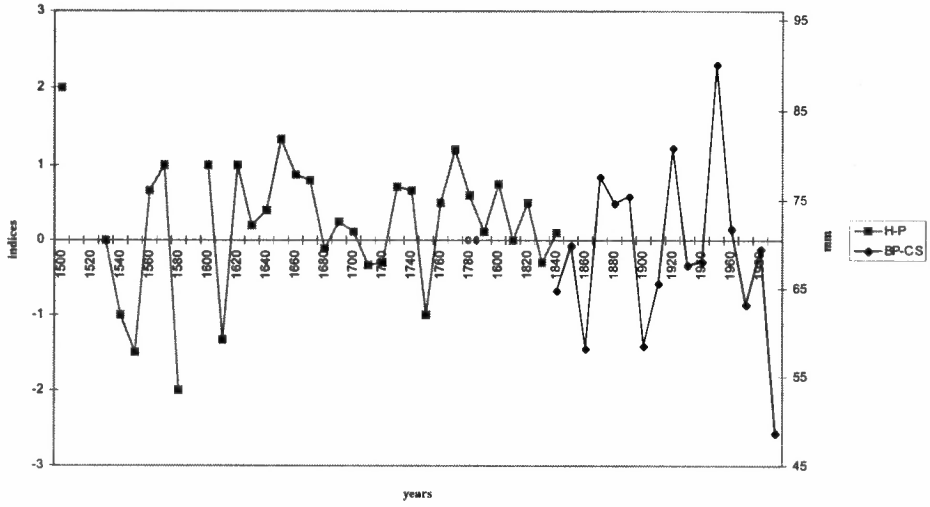
The months of June in the first half of the 19th century were stable with respect to average temperatures when compared with previous centuries and few temperature anomalies were noted. The early summer of **1817** was very warm in the Highlands (*Réthly*, 1998m:254). June of **1821** was cool and rainy in Transylvania according to 'Hazai és Külföldi Tudósítások' (Local and Foreign Reports) (*Réthly*, 1998m:300; H.K.T., 3rd October). Father *István Debreczeni* entered in his diary that the cold weather in June **1832** caused serious damage to crops in the Plain (*Réthly*, 1998m:884). The hot

and dry weather of early summer in **1833** caused only slightly less damage to the crops of the Highlands as well, again according to 'Hazai és Külföldi Tudósítások' (Local and Foreign Reports) (*Réthly*, 1998m:471; H.K.T., 13th July. The papers reported that June of **1834** brought heat and drought again (*Réthly*, 1998m:485; H.K.T., 5th July). In the early summer of **1839** the heat and countrywide drought caused serious damage to crops as reported in the 'Hazai és Külföldi Tudósítások' (Local and Foreign Reports) (*Réthly*, 1998m:584; H.K.T., 13th July).

According to the 100-year averages of Budapest temperature data, the weather during June months in the first and second third of the 19th century was mainly warm. The stable warm weather for 30 years, from the 1830s until the 1860s, deserves special attention. There was a significant cooling trend at the turn of the 20th century that bottomed out during the 1920s. During the second third of the 20th century there was a slight warming trend, but with significant deviation, reaching relative peaks in the 1930s and 1950s. In the 1980s, June months turned cooler again.

Figure 22 *June temperature and precipitation 10-year averages over the decades from the 16th century until today. The first diagram (1500-1850) is based on the time series of a history based climate reconstruction, while the second diagram is based on the time series for instrument observations from the Budapest observatory (1780-1996)*





4.6.2. June Precipitation Anomalies and Medium Term Trends

The scarcity of documentary sources for the 16th century prevents the determination of clear conclusions regarding variations in climate trends. Transylvanian records indicate that it rained nearly every day in June of **1508** (*Réthly*, 1962:60; *Bielz*, 1862-63:6). The early summer of **1549** brought long-lasting drought to Transylvania (*Réthly*, 1962:76; *Bielz*, 1862-63:11). A drought which started early in May of **1551** continued in the Highlands into June, scorching sprouting crops and drying the fields (*Réthly*, 1962:78; *Wagner*, 1774:II.57). There was not a drop of rain in Transylvania in June of **1585**, which significantly hindered corn growth (*Réthly*, 1962:99; *Hain D.*, 1853-54:11).

There were two early summers that experienced drought at the beginning of the 17th century. The Fauth Chronicle wrote that June of **1616** was so dry that wells ran dry in Transdanubia (*Réthly*, 1962:136). Both the Bruckner and Payr Chronicles reported in **1619** that the corn could not grow in Transdanubia due to a major drought (*Réthly*, 1962:140; *Payr*, 1942:14). The months of June turned wet after the decade of 1610 through the 1680s. It rained continuously from the 9th through the 12th of June **1658** according to the Payr Chronicle, preventing farmers from working their fields in Transdanubia, and the vineyards became overgrown with weeds (*Réthly*, 1962:188; *Payr*, 1942:51). The same region had similar rainy weather in June of **1663,** which again impeded agricultural work (*Réthly*, 1962:198; *Payr*, 1942:57). The Payr Chronicle reported that Transdanubia had a very dry June in **1666** (*Réthly*, 1962:202; *Payr*, 1942:63). Transylvanian records stated that the early summer of **1667** was unusually wet (*Réthly*, 1962:203; *Hain D.*, 1853-54:21).

The rates of June precipitation became more balanced at the turn of the 18th century with regard to 100-year averages, and there was an increase in both positive and nega-

tive precipitation anomalies as well. In June of **1681** there was no grass to cut in the Plain due to the drought (*Réthly*, 1962:224; *Takács*, 1910:63). June **1682** also brought drought, and *Gáspár Hain* reported water-shortages in the settlements of the Highlands, and mills going on 'bank-holidays' as well (*Réthly*, 1962:225; *Hain G.*, 1910-13:491). Transylvania received a lot of rain in the early summer of **1689**, wrote *Zsigmond Szaniszló*, which ruined the hay harvest (*Réthly*, 1962:344). Drought returned to Transylvania in June of **1690** (*Réthly*, 1962:238; *Cserei M.*, 1893:147), and a year later, in June of **1691** it rained continuously in this region for four weeks, causing rivers to flood and roads to be difficult to travel due to mud (*Réthly*, 1962:241; *Cserei M.*, 1893:152). *Andreas Loew* wrote in his diary that Transdanubia saw fine and rain-free weather in June of **1704** (*Réthly*, 1970:34; *Sydenham*, 1763:305). The early summer of **1708** passed without a single rain-free day in Transdanubia after the 8th of June reported *Dr. Loew* among his meteorological observations (*Réthly*, 1970:44; *Sydenham*, 1763:334). Transylvania experienced drought in June of **1710** to a degree never before experienced there, causing major damage to crops and vegetation (*Réthly*, 1970:51; *Cserei M.*, 1852:441). *János Ádám Reimann* wrote that the Highlands had an extremely dry June in **1724**, causing a scarcity of hay (*Réthly*, 1962:103; Sammlung, 1724:613), and this was the case again in the Highlands two years later, in June of **1726** causing significant damage to crops (*Réthly*, 1970:117; Sammlung, 1726:702).

From the 1730s onwards June became wet again, and this trend prevailed overall, but with wide variations, until the end of the 18th century. *János Ádám Reimann* recorded that June of **1730** was cool and rainy in the Highlands (*Réthly*, 1970:136; Nachrichten, 1730:919). Ten years later, in June **1740** it rained so much that the rivers in the Highlands and Transylvania flooded (*Réthly*, 1970:158; *Dongó*, 1900:IV.53). However, June of **1746** was dry in Transylvania, in the Plain and in Transdanubia (*Réthly*, 1970:175; *Apor*, 1863:323). The heat was so severe in the early summer of **1755** that early crops were scorched in the field in Transylvania (*Réthly*, 1970:192; *Vásárhelyi*, 1948:236). This region had floods again in **1767** due to June rains (*Réthly*, 1970:225; *Cserei Gy.*,1875:421). Father *István Körtvélyesi Jr.*, a Calvinist pastor, wrote that the Highlands experienced rainy weather throughout June of **1771** (*Réthly*, 1970:503). It was also *Körtvélyesi Jr.* who recorded that June of **1777** brought frequent rains to the Highlands (*Réthly*, 1970:505). The 'Pressburger Zeitung' also reported heavy rains in the same region in June **1781**, bringing floods that washed away the cut hay (*Réthly*, 1970:282; P.Z., 8th August). Early summer was dry again a year later, in **1782** according to the correspondents from the Plain and Highlands for 'Magyar Hírmondó' (Hungarian Messenger) (*Réthly*, 1970:294; M.H., 6th July). *Sámuel Benkő* observed rains and showers in June of **1786** (*Réthly*, 1970:527).

The dominance of rainy June months decreased significantly in the first half of the 19th century, but there were far more anomalies recorded than ever before. The Historia Domus of the Franciscan Monastery in Eger tells us of rains in June **1801** that caused damage to corn and vineyards (*Réthly*, 1998m:7). It rained for four weeks in Transdanubia and in the Highlands, wrote 'Pressburger Zeitung' in June **1803**, and the water level of the Danube was higher on the 21st of June than during the spring melt

(*Réthly*, 1998m:24; P.Z., 24th June). Early summer of **1811** was very dry, according to the Pest-Buda correspondent of 'Pressburger Zeitung', impeding crop growth (*Réthly*, 1998m:99; P.Z. 22nd June). An unknown diarist wrote that the Highlands experienced a cool and wet June in **1814** (*Réthly*, 1998m:172). The Buda observatory recorded fine, dry weather in the meteorological diary for June of **1818** (*Réthly*, 1998m:264; H.K.T., 11th July) but the same month two years later in **1820** was cool and rainy in the Highlands (*Réthly*, 1998m:294). The 'Hazai és Külföldi Tudósítások' (Local and Foreign Reports) reported in June of **1821** that constant rains destroyed the seedlings in the gardens and fields (*Réthly*, 1998m:300; H.K.T., 3rd October). Father *István Debreczeni*, however, recorded that in the early summer of **1822** the Plain saw no rain at all (*Réthly*, 1998m:876). Work in the fields suffered delays in Transylvania in June **1831** due to rain according to 'Hazai és Külföldi Tudósítások' (Local and Foreign Reports) (*Réthly*, 1998m:447; H.K.T., 20th July). Transylvania experienced a very dry June in **1833** wrote the papers of that time, with hay drying out in the fields and farmers fearing they would be unable to feed live-stock during following winter (*Réthly*, 1998m:471; H.K.T., 13th July). The dry weather of the previous year returned to Transylvania, the Plain and Transdanubia in early summer of **1834** (*Réthly*, 1998m:485; H.K.T., 5th July). June in **1836** was again dry and 'Erdélyi Hírlap' (Transylvanian News) reported that the fields in the Plain were totally scorched (*Réthly*, 1998m:515; E.H., 23rd July). The year **1837** finally brought a wet June, but the constant rains destroyed the belt of hay in the Plain, the hay turning black in the fields (*Réthly*, 1998m:542; H.K.T., 1st July). Two years later, June **1839** was so dry, wrote 'Hazai és Külföldi Tudósítások' (Local and Foreign Reports), that there were one-inch-deep rents in the soil of the Plain (*Réthly*, 1998m:585; H.K.T., 13th July). The Historia Domus of the Franciscan Monastery in Jászberény recorded that late spring and early summer of **1846** brought very dry weather to the Plain (*Réthly*, 1998m:685).

The 100-year averages of the Budapest precipitation time series show that June precipitation rates varied greatly. In the 19th century, the 1860s were extremely dry, while precipitation levels increased significantly in the last third of the century. The first decade of the 20th century brought extreme drought but was followed by a long period of greatly increased June precipitation levels until it reached the peak of the century in the 1950s. The months of June in the last third of our century turned somewhat drier.

4.6.3. June Climate Change Trends over the Centuries

Temperature

The time series of 50-year averages calculated on the index values of the historical climate reconstruction show a cooling trend for three and a half centuries, but except for the second half of the 18th century, this occurred within the slightly warmer domain than the average. The data of the Budapest temperature time series shows that the drop in average June temperatures continued until the mid-20th century, while the months of June turned much warmer in the second half of our century.

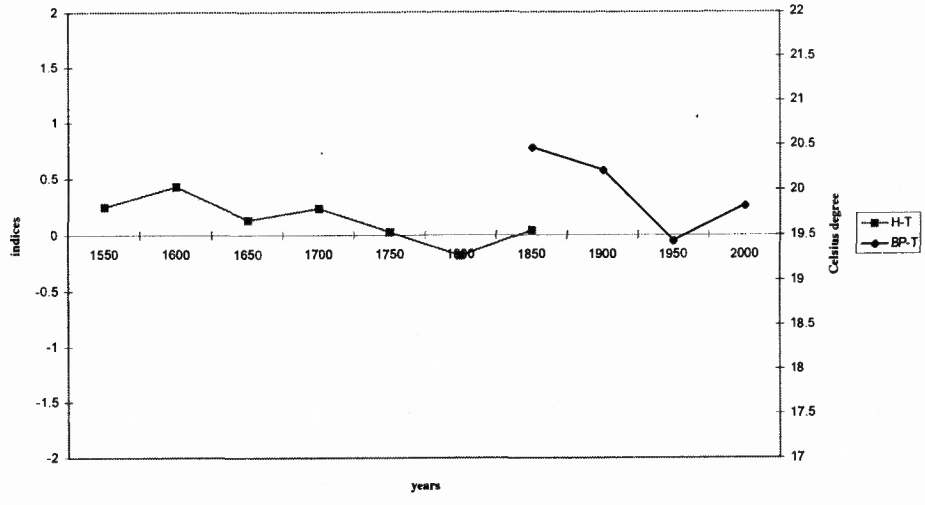
Precipitation

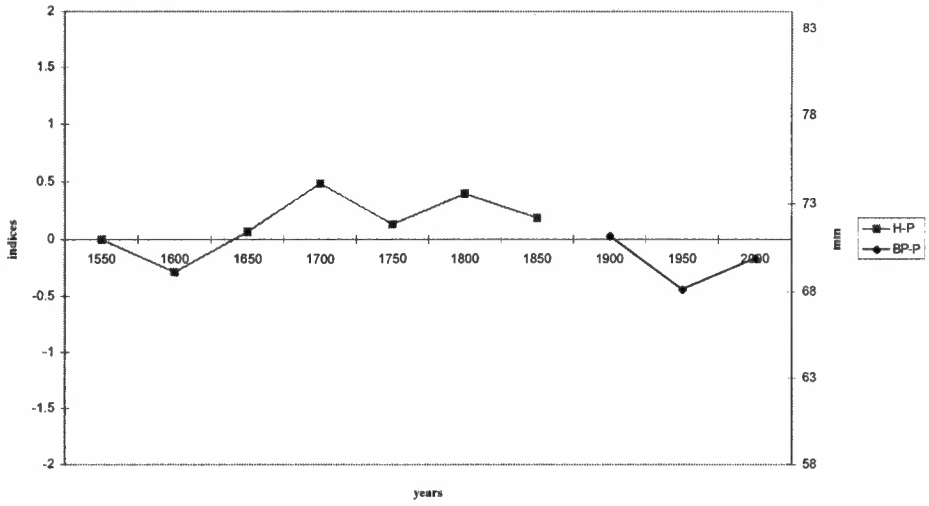
According to the few sources of information available, June months of the 16th century were rather dry, but it can be stated that early summer was slightly wetter from the turn of the 17th century until the middle of the 19th century. Two peaks can be marked within this wet period, one in the second half of the 17th century, and another in the second half of the 18th century. The Budapest documentary precipitation time series shows a drying trend between the second half of the 19th century and the first half of the 20th century, while the months of June became wetter again in the second half of our century.

Climate Change Characteristics

Four distinct climate types can be distinguished for June months within the five hundred years analyzed here. The months of June in the 16th century were mostly warm and dry. The characteristic climate from the turn of the 17th century until the mid-18th century was warm but wet. June weather from the second half of the 18th century until the middle of the 19th century was slightly cooler and wetter than the overall average. The time series derived from instrument-based observations in Budapest show that June temperatures and precipitation rates varied in unison with each other. The period of lower temperatures that lasted until the mid-20th century saw lower precipitation rates as well, while the second half of the century brought not only higher temperatures, but higher precipitation levels as well.

Figure 23 *June temperature and precipitation 50-year averages over the decades from the 16th century until today. The first diagram (1500-1850) is based on the time series of a history based climate reconstruction, while the second diagram is based on the time series for instrument observations from the Budapest observatory (1780-1996)*





4.7. July

4.7.1. July Temperature Anomalies and Medium Term Trends

The July temperature indexes of the historical climate reconstruction show that the July mean temperature was a bit warmer than the average except for a few exceptions, and that most of the anomalies were positive ones.

In **1551** the Highlands experienced an extreme heat and drought starting from the feast of '*Fülöp* and *Jakab*' (the 1st of May) until that of '*Maria Magdolna*' (the 22nd of July) which scorched crops in the fields (*Réthly*, 1962:78; *Wagner*, 1774:II.57). *Istvánfi*'s chronicle reads that the weather was again very warm in the Highlands (*Réthly*, 1962:82; *Istvánfi*, 1867-71:423).

The hot and dry weather of July **1607** caused forest-fires in Transdanubia, and interfered with the growth of the hay as well (*Réthly*, 1962:125). July **1683** brought broiling summer heat to the Highlands (*Réthly*, 1962:227; *Babotsay*, 1901:11). *Andreas Loew* wrote that it was so warm in July of **1688** in the Highlands that the people felt as if the 'sky was on fire' (*Réthly*, 1962:236; *Sydenham*, 1763:288).

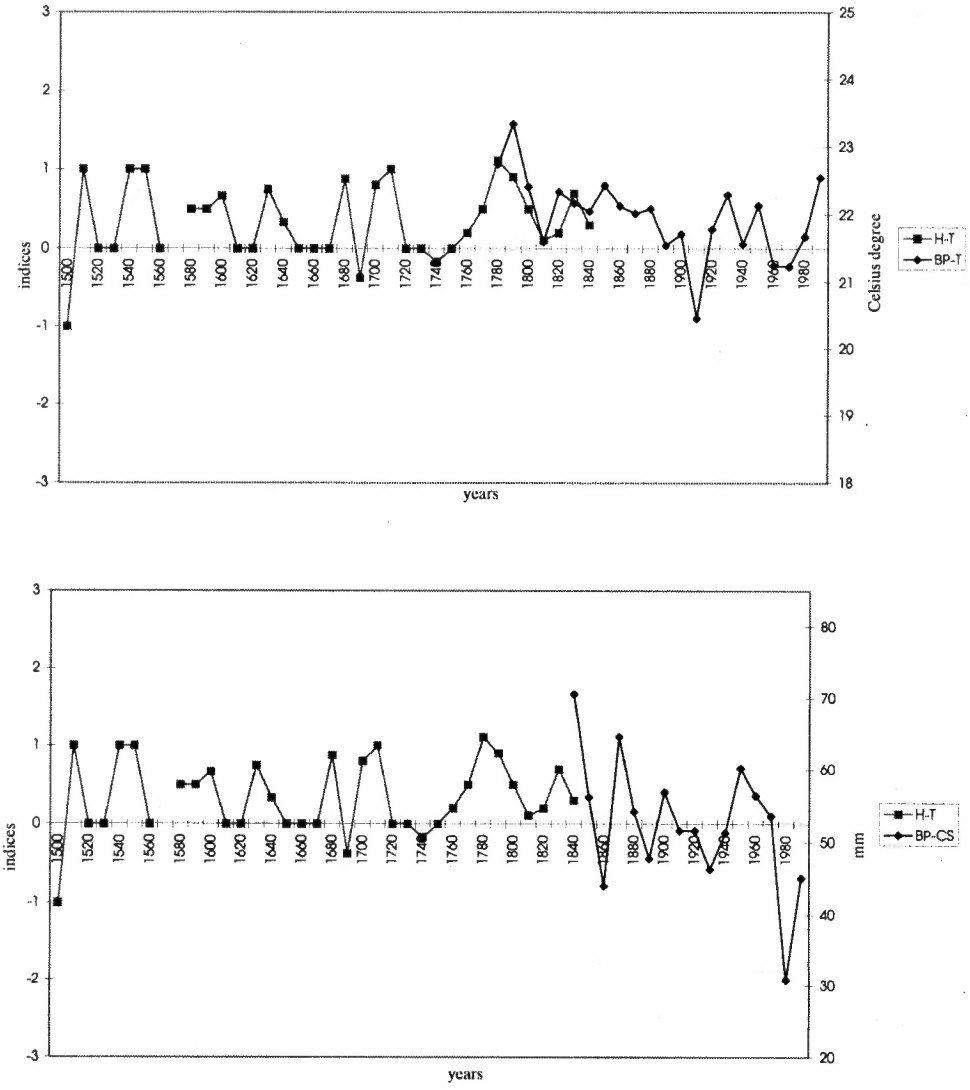
According to *Loew*'s notes from **1701**, Transdanubia had a very warm mid-summer that year (*Réthly*, 1970:27; *Sydenham*, 1763:297). July of **1706** was extremely hot in Transdanubia, it did not cool off at night either, wrote *Loew* (*Réthly*, 1970:38; *Sydenham*, 1763:318). There are records available about the heat and dry weather in Transylvania in **1710** (*Réthly*, 1970:51; *Cserei M.*, 1852:441). *Loew*'s meteorological observations prove that the series of hot midsummers continued in July of **1712** (*Réthly*, 1970:57; *Sydenham*, 1763:242). The first cold anomaly dates from July of **1761**

as documented in the Transylvanian records (*Réthly*, 1970:200; *Cserei Gy.*, 1875:373). It was also noted in Transylvanian diaries that July **1763** was hot and dry (*Réthly*, 1970:205; *Cserei Gy.*, 1875:375). The 'Pressburger Zeitung' reported that July of **1778** was so hot that the farmers could work only at night in the Plain (*Réthly*, 1970:252-254; P.Z., 25th and 29th July, 5th August). The middle of the summer in **1782** was again extremely warm and 'Magyar Hírmondó' (Hungarian Messenger) reported that the temperature in the Highlands reached as high as 33,8 °C (*Réthly*, 1970:295; M.H., 31st July and 7th September). July of **1783** was not only hot, but the correspondents of 'Pressburger Zeitung' from Transylvania wrote about an unusual dry fog probably caused by volcanic dust in the atmosphere after the eruption of the Hekla volcano in Iceland (*Réthly*, 1970:304; 30th July). The Highlands experienced heat and drought in July **1788** according to the 'Pressburger Zeitung', and there were forest-fires in various places (*Réthly*, 1970:353; P.Z., 2nd August). Mid-summer of **1792** passed with very warm weather in the Highlands, noted *Sámuel Benkő* in his diary (*Réthly*, 1970:529). A year later it was again broiling hot in the Highlands (*Réthly*, 1970:530). The last July temperature anomaly of the 18th century was a positive one in **1797** when the Buda-correspondent of 'Magyar Kurír' (Hungarian Courier) wrote that wells ran dry and grazing lands were scorched due to the hot, dry weather (*Réthly*, 1970:440; M.K., 28th July).

'Vereinigte Pester und Ofner Zeitung' reported in July **1802** that it was hard to stand the heat in the Plain (*Réthly*, 1998m:18; V.O.P.Z., 1st August). Mid-summer of **1811** brought heat and drought to the Highlands reported the 'Pressburger Zeitung' (*Réthly*, 1998m:99; P.Z., 2nd August). An unknown diarist recorded that Transdanubia experienced a lengthy spell of hot weather in July **1817** (*Réthly*, 1998m:254). *Mihály Király*, a Calvinist pastor, recorded that July **1830** brought hot, alternately dry and stormy weather to Transylvania (*Réthly*, 1998m:970). Transdanubia and the Plain had a hot, dry mid-summer in **1834** wrote the Buda-correspondent for 'Hazai és Külföldi Tudósítások' (Local and Foreign Reports) (*Réthly*, 1998m:485; H.K.T., 13th August). July of **1839** was again reported by newspapers to be hot and dry in Transdanubia (*Réthly*, 1998m:591; H.K.T., 17th August). *Gábor Ecsedy*, another Calvinist pastor noted in his diary that July of **1841** was hotter than he had ever experienced before with temperatures occasionally reaching as high as 45 °C (*Réthly*, 1998m:1146).

According to the averages of the Budapest temperature time series over the centuries, midsummer of the first two thirds of the19th century brought mostly warm weather. July turned cooler in the last third of the 19th century, and in the first decades of the 20th century, with the 1910's being particularly cold. The July months warmed up again in the middle third of the 20th century, with the years of the 1930s and 1950s outstandingly warm. Mid-summer became cooler again in the 1960s and 1970s, while a significant warming trend started in the 1980s and continues until today.

Figure 24 *July temperature and precipitation 10-year averages over the decades from the 16th century until today. The first diagram (1500-1850) is based on the time series of a history based climate reconstruction, while the second diagram is based on the time series for instrument observations from the Budapest observatory (1780-1996)*



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4.7.2. July Precipitation Anomalies and Medium Term Trends

The July precipitation time series of the historical climate reconstruction show a stable precipitation surplus from the beginning of the 16th century until the mid-19th century, but despite the positive precipitation balance, there were several anomalies towards both extremes.

It rained without interruption for the duration of July **1508**, according to Transylvanian Saxon sources (*Réthly*, 1962:60; *Bielz*, 1862-63:6). Turkish historians wrote in **1532** that the wet July and the spates of the Transdanubian rivers caused a lot of problems for troops moving against Vienna (*Réthly*, 1962:67; *Thúry*, 1893:I.353). The dry weather that started in the spring of **1549** remained through mid-summer as well and Transylvanian Saxon sources reported that many wells and rivers dried up, and that there were forest-fires due to the drought (*Réthly*, 1962:76; *Hain D.*1853-54:8). The drought that started in May of **1551** endured until the end of July causing serious damage to crops (*Réthly*, 1962:78; *Wagner*, 1774:II.57). *Lestár Gyulafy* recorded in July **1552** that the siege of the royal troops at Cluj (H-Kolozsvár) failed due to the constant rain (*Réthly*, 1962:78; *Gyulafy*, 1893:116). The wet July of **1566** in the Plain prevented the Turkish siege at the fortress of Gyula from succeeding (*Réthly*, 1962:88; *Istvánfi*, 1867-71:527). *Sebestyén Borsos* wrote in his chronicle that there was not a drop of rain in July of **1580** in Transylvania (*Réthly*, 1962:96; *Borsos*, 1855:25).

Mid-summer of **1607** was hot and dry, according to the Bruckner Chronicle, causing forest-fires and severe crop damage in Transdanubia (*Réthly*, 1962:125). *Gáspár Hain* wrote that July **1628** brought unusually wet weather to the Highlands, causing rivers to flood resulting in major material damages (*Réthly*, 1962:148; *Hain G.*, 1910-13:185), and *Prince Miklós Eszterházy* wrote in his letter from Transdanubia that it was impossible to run on the muddy and flooded roads (*Réthly*, 1962:148; *Eszterházy*, 1909:41). *Ambrus Keczer*'s notes indicate that mid-summer of **1665** was very wet in the Highlands, with rainy weather and the resulting floods delaying agricultural work (*Réthly*, 1962:285). A year later, July of **1666** brought totally different weather and the Payr Chronicle reported that the whole month passed without any rain at all (*Réthly*, 1962:202; *Payr*, 1942:63). Saxon sources from Transylvania state that the weather in July **1667** turned wet again, with rain falling throughout the month, bringing floods that prevented the harvesting of the crops (*Réthly*, 1962:203; *Hain D.*, 1853-54:21). A year later July of **1668** again brought long periods of rain and floods in Transylvania (*Réthly*, 1962:205; *Bielz*, 1862-63:71). Mid-Summer of **1681** was again very dry, and there were no grasses at all to cut in the Plain (*Réthly*, 1962:224; *Takács*, 1910:63). *Andreas Loew*'s weather observations show that Transdanubia had a very hot and dry July in **1688** (*Réthly*, 1962:236; *Sydenham*, 1763:236). Saxon sources from Transylvania reported that it rained continuously in July of **1698** causing floods (*Réthly*, 1962:256; *Bielz*, 1862-63:57).

Transylvania saw rain every day in July of **1705**, causing floods that washed away bridges (*Réthly*, 1970:35; *Bielz*, 1862-63:57). Five years later, in **1710** the people of Transylvania experienced a drought the likes of which they had never seen before

(*Réthly*, 1970:51; *Cserei M.*,1893:441). There was also a great drought in July of **1728**, noted by *György Buchholtz* in his meteorological diary, which led to forest-fires in the Highlands, while the parched fields resulted in the deaths of many animals in the Plain (*Réthly*, 1970:129; Nachrichten, 1728:1197,1326). There are documentary sources referring to drought in Transylvania in July of **1742** (*Réthly*, 1970:165; *Clauser*, 1937:230). Transylvania had drought again in **1759**, which caused a shortage of hay (*Réthly*, 1970:197; *Cserei Gy.*, 1875:356). Transylvanian reports say that July of **1763** brought hot and dry weather (*Réthly*, 1970:205; *Cserei Gy.*, 1875:375). According to *Sámuel Benkő*'s weather records, mid-summer of **1782** went by with hot dry weather (*Réthly*, 1970:525). The Buda correspondent of 'Magyar Kurír' (Hungarian Courier) reported that July **1797** brought heat and drought, most wells dried up, and the fields were scorched dry by the heat (*Réthly*, 1970:440; M.K., 28th July).

The Historia Domus of the Franciscan Monastery in Eger recorded that the Highlands experienced constant rain in July of **1801** causing considerable damage to crops (*Réthly*, 1998m:7). The 'Pressburger Zeitung' reported in July **1811** that the Highlands had very warm and steady dry weather (*Réthly*, 1998m:99; P.Z., 2nd August). Early summer was warm and dry in the Highlands in **1817**, and there was precipitation in the form of hail (*Réthly*, 1998m:254). The Historia Domus of the Franciscan Monastery in Jászberény recorded that the whole summer of **1822**, but primarily July, was so dry in the Plain that the recently planted crops could not produce any harvest (*Réthly*, 1998m:320). July of **1825** was extremely wet, with heavy rains causing spates, reported the Pest-Buda correspondent of 'Hazai és Külföldi Tudósítások' (Local and Foreign Reports) (*Réthly*, 1998m:356; H.K.T., 30th June). Mid-summer of **1827** was hot and dry in the Plain according to the Historia Domus of the Franciscan Monastery of Jászberény (*Réthly*, 1998m:382). The 'Hazai és Külföldi Tudósítások' (Local and Foreign Reports) reported that the Highlands received just a little rain in July **1830** (*Réthly*, 1998m:439; H.K.T., 3rd August). July **1831** on the other hand was extremely wet in Transylvania, which delayed the harvest (*Réthly*, 1998m:447; H.K.T., 20th July). The Plain experienced uninterrupted rain in the mid-summer of **1833** which hindered the harvest, noted the 'Hazai és Külföldi Tudósítások' (Local and Foreign Reports) (*Réthly*, 1998m:472; H.K.T., 31st August). July **1834** brought extreme heat and drought to the Highlands (*Réthly*, 1998m:486; H.K.T., 23rd July). 'Erdélyi Híradó' (Transylvanian Reports) reported that drought caused considerable suffering in Transdanubia in July **1836** when the water-mills stopped working and there were rents in the fields of 5-8 cm wide and 32-64 cm deep (*Réthly*, 1998m:516; E.H., 30th July). The 'Hazai és Külföldi Tudósítások' (Local and Foreign Reports) reported that Transylvania received constant rain in July of **1837** with rivers flooding in several areas covering farm land and hay-fields (*Réthly*, 1998m:543; H.K.T., 16th August). Transdanubia had drought-like conditions in July of **1839,** which delayed the growth of the crops on the farms (*Réthly*, 1998m:587; H.K.T., 7th August). 'Nemzeti Újság' (National Paper) reported that Transdanubia and the Highlands had cool and dry weather in July **1842** (*Réthly*, 1998m:635; N.Ú., 16th and 30th July). The Historia Domus of the Franciscan Monastery in Kecskemét recorded that July of **1846** was so dry that

the fields were totally scorched, and the live-stock was driven afield just out of habit (*Réthly*, 1998m:687).

The averages of the Budapest precipitation time series by century show extreme fluctuations. Average rainfall in the first decade of the time series (1840s) was 70,5 mm, while it was only 30,8 mm in the 1980s. The 10-year precipitation averages for July varied between these values from decade to decade. According to the records particularly dry decades occurred in the 1860s, 1890s, 1930s and the years of the 1980s previously mentioned. The following decades were, conversely, conspicuously wet: the 1840s, 1870s, 1900s, 1950s and 1960s.

4.7.3. July Climate Change Trends over the Centuries

Temperature

The 50-year averages of the historical climate reconstruction indexes show that the July months were slightly warmer than the 0-value considered to be the average. The fairly stable diagram has lower values in the second half of the 17th century, and slightly higher values in the second half of the 18th century. The combination of the historically reconstructed data and the Budapest instrumental based data results in a time series that shows a cooling trend starting at the beginning of the 19th century that lasts until the middle of the 20th century. In the second half of the 20th century, the months of July turned slightly warmer.

Precipitation

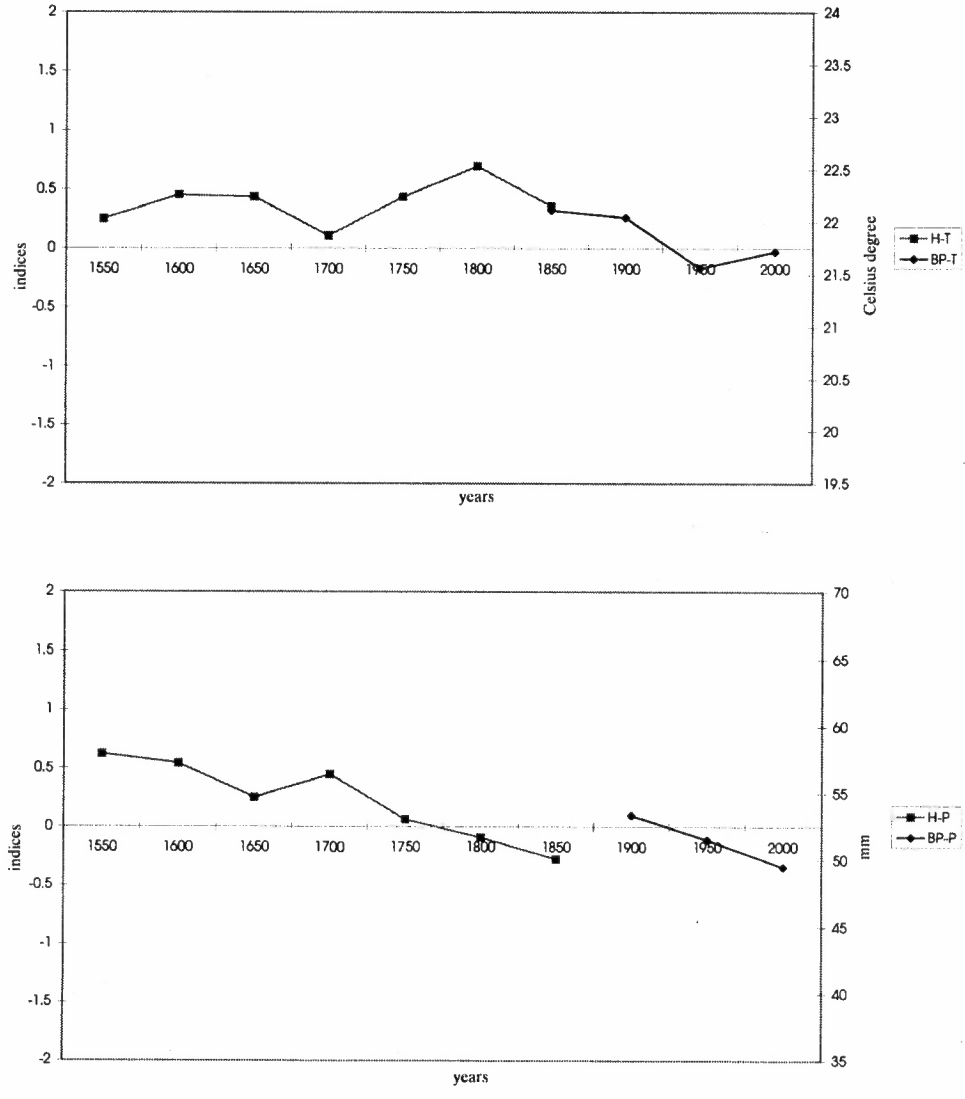
The combination of the historically reconstructed data and the Budapest instrumental based data results in a time series that seems to outline a five hundred year process of July months becoming increasingly dry. Nevertheless this tendency towards drier weather took place in overall wet circumstances until the end of the 18th century, and the really dry climatic conditions became dominant only during the first half of the 19th century.

Climate Change Characteristics

The July months from the end of the 16th century until the second half of the 18th century were mostly warmer and wetter than the average, while the average temperature remained relatively high in the second half of the 19th century as well, but July weather became drier.

The data of the Budapest instrument based time series show that both the average temperature and precipitation dropped until the middle of the 20th century, while the second half of our century brought a further drop in temperature combined with a rise in precipitation.

Figure 25 *July temperature and precipitation 50-year averages over the decades from the 16th century until today. The first diagram (1500-1850) is based on the time series of a history based climate reconstruction, while the second diagram is based on the time series for instrument observations from the Budapest observatory (1780-1996)*



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4.8. August

4.8.1. August Temperature Anomalies and Medium Term Trends

The average temperatures of August months over the decades of the 16th century varied significantly and did not show a stable medium-term trend. There is no knowledge of remarkable temperature anomalies for August during this time period.

August turned warmer from the beginning of the 17th century until the first decade of the 18th century when, coincidentally, the first positive anomalies occurred. *Gáspár Hain* wrote in his chronicle that the Highlands had a heat wave in August **1622** (*Réthly*, 1962:144; *Hain G.*, 1910-13:161). *György Dobronoki* noted that the weather was extremely warm and dry in the Highlands in August of **1637** (*Réthly*, 1962:278). The only negative temperature anomaly of the century was in August of **1641**, when *Gáspár Hain* recorded that the vegetable crops in the Highlands were destroyed by the cold weather, that it snowed in the mountains and there were even frosts (*Réthly*, 1962:164; *Hain G.*, 1910-13:199). August of **1661** was unusually warm with the constant heat causing considerable discomfort for the royal troops traveling from the Highlands to Transylvania (*Réthly*, 1962:192; *Speisser*, 1712:520). The Diarium of the Order of Jesuits in Kasse recorded a very hot late summer in **1678** (*Réthly*, 1962:364). *Andreas Loew* reported that in August of **1701** not only were the days hot in Transdanubia, but the nights as well (*Réthly*, 1970:27; *Sydenham*, 1763:297), while the late summer of **1703** brought a spell of cool weather (*Réthly*, 1970:32; *Sydenham*, 1763:301). August of **1705** brought heat again to Transdanubia (*Réthly*, 1970:36; *Sydenham*, 1763:312) as did the following year in **1706** when grapes were already ripe and on sale at the beginning of August in Transdanubia (*Réthly*, 1970:38; *Sydenham*, 1763:318). The century long trend of warm August months ended with a cold late-summer in **1707**, when *Andreas Loew* wrote about cool, rainy and unpleasant windy weather (*Réthly*, 1970:41; *Sydenham*, 1763:328-329).

From the 1720s until the 1750s the months of August were mostly free of extremes, except for **1725** which saw a cool and rainy August. This weather in the Highlands was recorded by *János Ádám Reimann* (*Réthly*, 1970:111; Sammlung, 1726:153).

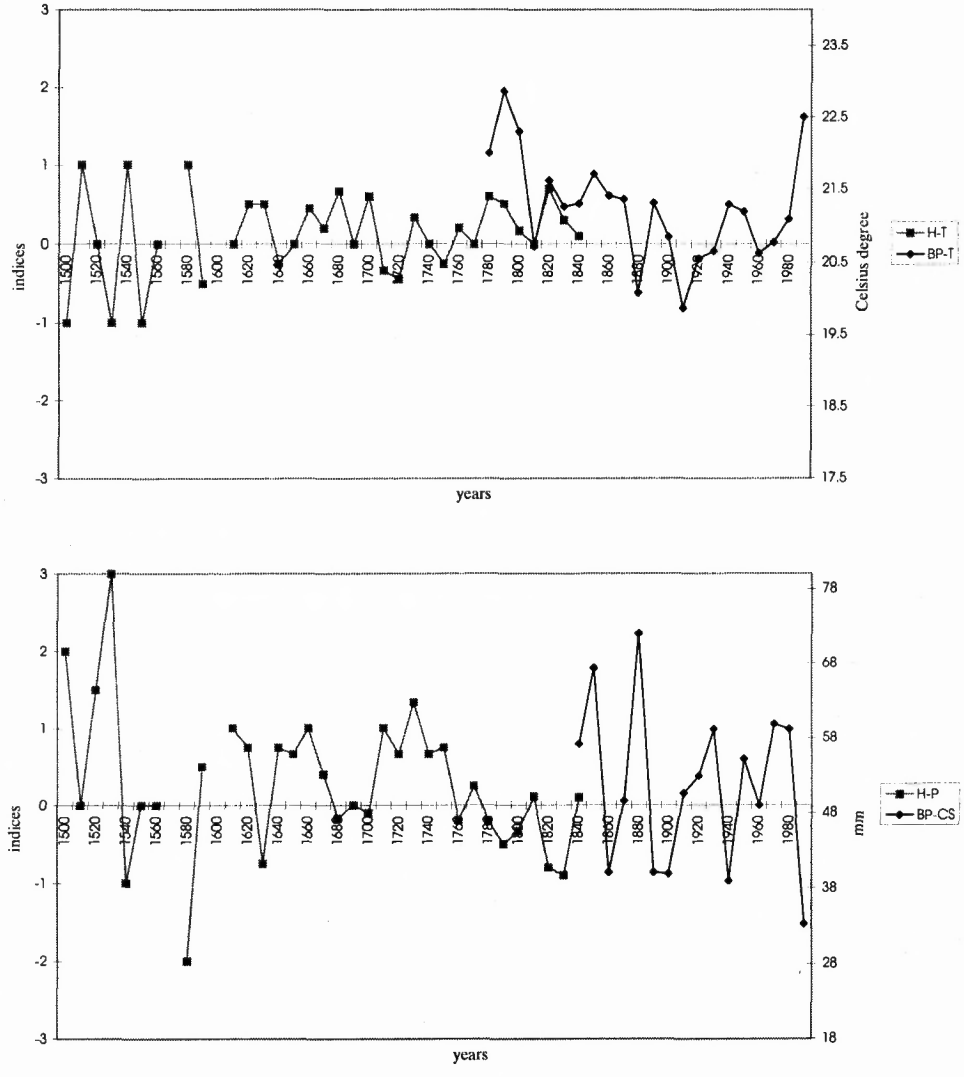
The August temperatures turned warmer again in the last third of the 18th century, and the number of positive temperature anomalies increased. Transylvanian sources reported that August of **1763** was extremely hot and dry (*Réthly*, 1970:205; *Cserei Gy.*, 1875:375). 'Magyar Hírmondó' (Hungarian Messenger) noted that August of **1781** was so hot that the temperatures in the Plain reached as high as 41,2 °C (*Réthly*, 1970:284; M.H., 5th and 29th September) while other papers noted that the heat in the Plain was difficult to bear (*Réthly*, 1970:296). According to 'Magyar Hírmondó' (Hungarian Messenger), the weather was hot and dry in August of **1782** in the Hungarian Plain (*Réthly*, 1970:296; M.H., 7th September) 'Magyar Hírmondó' (Hungarian Messenger) reported that the heat and drought of August **1784** (*Réthly*, 1970:318; M.H., 25th September) hit every region of the country. According to 'Ephemerides Budenses', the

weather was hot and dry in August of **1791** both in Transdanubia and the Plain (*Réthly*, 1970:383; E.B. 26th August). August **1807** was recorded as one of the warmest late-summers of the Buda time series and the 'Pressburger Zeitung' reported that Transdanubia experienced a continuous heat wave for the duration of the month (*Réthly*, 1998m:56; P.Z., 4th September).

Most of the August months in the first half of the 19th century were warm with the most significant warming trend taking place in the 1820s and 1830s. Late summer of **1820** brought extraordinary heat both to the Plain and the Highlands (*Réthly*, 1998m:294). 'Hazai és Külföldi Tudósítások' (Local and Foreign Reports) wrote that August in **1822** was so hot that the grapes of the Buda area vineyards had ripened by the middle of the month (*Réthly*, 1998m:321; H.K.T., 31st August). *Mihály Király*, a Calvinist pastor noted that August **1824** brought oppressive heat to Transylvania (*Réthly*, 1998m:953). The 'Pressburger Zeitung' reported that late summer in **1830** brought such hot and dry weather to the Highlands that the grazing lands were scorched, and the corn crop dried out in the fields (*Réthly*, 1998m:439; P.Z., 27th August). The only negative exception of the temperature anomalies was in August of **1833** when the 'Hazai és Külföldi Tudósítások' (Local and Foreign Reports) wrote about cool, rainy weather in the Highlands (*Réthly*, 1998m:474; H.K.T., 31st August). *László Zlinszky* noted in August **1834** that late summer was again very hot (*Réthly*, 1998m:936). *Gábor Ecsedy*, a Calvinist pastor spoke about the weather of August **1838** being unusually cool and clouded in the Plain (*Réthly*, 1998m:1129). 'Hazai és Külföldi Tudósítások' (Local and Foreign Reports) reported that late summer in **1839** brought heat and drought never experienced before in Transylvania (*Réthly*, 1998m:591; H.K.T., 12th October). It was again *Gábor Ecsedy*, a Calvinist pastor, who characterized the weather of August **1841** as unusually warm and dry in the Plain (*Réthly*, 1998m:1147). Heat and drought also characterize the weather in Transylvania in the late summer of **1850** (*Réthly*, 1998m:718; M.H., 25th September).

According to the 100-year averages of the Budapest temperature time series, the latter decades of the 18th century brought warm later summers, and this predominantly warm characteristic of August months continued until the 1870s. Yet August became significantly cooler by the end of the 19th century, particularly in the decades of the 1880s, 1910s, 1920s and 1930s. August turned warmer again in the mid-20th century, but the 1960s brought cooler weather again. A significant warming trend began in the 1970s and continues to this day.

Figure 26 *August temperature and precipitation 10-year averages over the decades from the 16th century until today. The first diagram (1500-1850) is based on the time series of a history based climate reconstruction, while the second diagram is based on the time series for instrument observations from the Budapest observatory (1780-1996)*



4.8.2. August Precipitation Anomalies and Medium Term Trends

While there is a scarcity of source material available from the first half of the 16th century, the data we do have shows that the August months of that time were wet. Saxon sources wrote in **1508** that it rained continuously in Transylvania until St. Bartholomew Day (24 August) (*Réthly*, 1962:60; *Bielz*, 1862-63:6). August of **1526** was remarkably wet also, hindering the movement of troops of *Suleyman I* through Transdanubia, then causing the Csele Stream to flood and claim the life of the Hungarian king, *Lajos II* who drowned dressed in heavy armour. *Istvánfi* describes this unfortunate incident in detail in his chronicle (*Réthly*, 1960:155; *Istvánfi*, 1867-71:155). Turkish sources show that the Turkish army moving against Vienna, but bivouacked at the fortress of Kőszeg in Transdanubia, suffered a lot due to the wet late summer of **1532** (*Réthly*, 1962:67; *Thúry*, 1893:I.354).

There are too few sources available to properly evaluate the climate history in the second half of the 16th century. One single anomaly was recorded as far as we know, when *Sebestyén Borsos* wrote in his chronicle that there was not a single drop of rain in Transylvania until St. Bartholomew's day (24 August) in **1580** (*Réthly*, 1962:96; *Borsos*, 1855:25).

The months of August were mostly wet in the first two thirds of the 17th century. Saxon sources in the Highlands reported drought conditions in August of **1633** (*Réthly*, 1962:153; *Wagner*, 1774:II.68). *György Dobronoki* wrote in this diary that the Highlands had an unusually warm and dry August in **1637** (*Réthly*, 1962:278). Continuous rains hit Transdanubia in August **1647**, wrote the Payr Chronicle (*Réthly*, 1962:177; *Payr*, 1942:35), and later, in **1652,** it reported that Transdanubia saw no rain at all in the late summer and early autumn (*Réthly*, 1962:181; *Payr*, 1942:41). Dissimilarly, August in the year **1657** brought heavy rains again to Transdanubia and resulted in blue mold rot in the vineyards in many areas (*Réthly*, 1962:186; *Payr*, 1942:50-51). It was *Gáspár Hain* who commented that the rains in August of **1659** delayed the harvest in the Highlands (*Réthly*, 1962:188; *Hain G.*, 1910-13:281). The late summer of **1665** passed with extensive rains in the Highlands causing floods (*Réthly*, 1962:201; *Guzich*, 1889:447). Saxon sources from Transylvania wrote in **1667** that rains since the end of June caused floods (*Réthly*, 1962:204; *Bielz*, 1862-63:54; *Hain D.,* 1853-54:21), and the rain in August of **1675** caused unprecedented flooding in Transylvania and serious damage to crops (*Réthly*, 1962:213; Székely Archives, 1934:353).

Late-summer weather became much drier at the turn of the 18th century. August of **1683** brought stable dry weather to Transylvania, wrote *Zsigmond Szaniszló* (*Réthly*, 1962:385), while *Andreas Loew* recorded heat and drought conditions in Transdanubia for the late summer of **1701** (*Réthly*, 1970:27; *Sydenham*, 1763:297).

August months during the first two thirds of the 18th century were also mostly wet. Late summer of **1712** was mostly rainy in Transdanubia (*Réthly*, 1970:57; *Sydenham*, 1763:242). *István Pál Bácsmegyei* reported in **1720** that it was raining in the Highlands for the whole month of August except for three days, and that the high levels of precipitation caused the corn 'to germinate on the land' (i.e. without being planted) (*Réthly*,

1970:86; Sammlung, 1720:140). *János Ádám Reimann* wrote about cool and rainy weather in the Highlands in August **1725**, and remarked on floods after the spring snow melt (*Réthly*, 1970:111; Sammlung, 1726:153). Two years later, in **1727** *Reimann* reported again that it rained nearly every day in the Highlands in August (*Réthly*, 1970:124; Sammlung, 1727:454). *György Buchholtz* noted in this meteorological diary that late summer of **1734** brought very wet weather destroying a significant amounts of produce (*Réthly*, 1962:144; *Weber*, 1896:146). Transylvania had drought in August of **1740** (*Réthly*, 1970:161; *Apor*, 1863:210), while late summer in **1751** was wet again in Transylvania (*Réthly*, 1970:187; *Vásárhelyi*, 1948:236).

The period from the 1760s until almost the middle of the 19th century brought mostly dry weather in August. Transylvania suffered from a drought in August of **1763** such that the leaves withered and fell (*Réthly*, 1970:205; *Cserei Gy.*, 1875:375). August of **1767** was one of the last rainy late summers and Transylvanian sources wrote that the high precipitation levels destroyed the corn crops (*Réthly*, 1970:225; *Halmágyi*, 1906:324). August of **1781** brought excessive heat and a drought to the Plain and there remained hardly any viable grazing lands for the animals, according to 'Magyar Hírmondó' (Hungarian Messenger) (*Réthly*, 1970:284; 29th September). In the late summer of **1782** dry weather was predominant once again in the Plain (*Réthly*, 1970:296; M.H., 7th September). Two years later, in August of **1784** the 'Magyar Hírmondó' (Hungarian Messenger) reported that the drought was so serious that the small branch of the Danube completely dried up between the Highlands and Transdanubia (*Réthly*, 1970:318; M.H., 25th September). Transylvania also had a dry late summer in **1788** (*Réthly*, 1970:354; M.K., 30th August). August **1791** brought drought-like weather conditions to the Pest-Buda area that caused crops and trees to dry out, as recorded in the 'Ephemerides Budensis' (*Réthly*, 1970:383; E.B., 26th August). The 'Magyar Kurír' (Hungarian Courier) wrote in the late summer of **1794** that lakes and marshes dried up in the Highlands due to the drought, and the moss in the marshes caught fire in several places (*Réthly*, 1970:416; M.K., 9th September). Both 'Pressburger Zeitung' and 'Vereinigte Ofner und Pester Zeitung' reported that August **1801** brought cool and rainy weather to the Plain and Transdanubia (*Réthly*, 1998m:10; P.Z., 1st September; V.O.P.Z., 20th August). The Highlands saw not a drop of rain in August **1804**, noted the Historia Domus of the Franciscan Monastery in Eger (*Réthly*, 1998m:38). The Historia Domus of the Franciscan Monastery mentions the drought in the Plain in the late summer of **1807** in Kecskemét (*Réthly*, 1998m:55). The August months in **1810** and **1811** brought fine, warm and dry weather to the Plain (*Réthly*, 1998m:93,104; *Magdics*, 1888:165). The Plain experienced broiling hot and dry weather in August of **1820** (*Réthly*, 1998m:292) and the grapes were already ripe in August due to the warm weather, as reported by the Pest-Buda correspondent for 'Hazai és Külföldi Tudósítások' (Local and Foreign Reports) (*Réthly*, 1998m:289; H.K.T., 19th August). The same paper reported a drought that lasted until the end of August in **1822** (*Réthly*, 1998m:321; H.K.T., 31st August). Late summer of **1824** also brought dry weather to the Pest-Buda region, which was reported in several different papers (*Réthly*, 1998m:345; H.K.T., 28th August). 'Pressburger Zeitung' also reported that a

drought in August **1830** caused considerable damage to crops (*Réthly*, 1998m:439; P.Z., 27th August). Three years later August of **1833** turned unusually cold and rainy, with high precipitation levels delaying the corn harvest (*Réthly*, 1998m:473; H.K.T., 31st August). *László Zlinszky* noted in this diary that all three summer months in **1834** brought drought-like conditions (*Réthly*, 1998m:518). A severe drought in August of **1836** in the Plain caused grazing lands to become scorched, wrote the 'Erdélyi Híradó' (Transylvanian Messenger), so the live-stock was driven into the harvested fields to graze (*Réthly*, 1998m:518; E.H., 3rd September). 'Hazai és Külföldi Tudósítások' (Local and Foreign Reports) wrote that August of **1839** brought severe heat and dry weather to Transylvania unlike anything ever experienced before, and the shortage of rain caused the crops to die and grazing-lands to become parched and burned by the heat and the sun (*Réthly*, 1998m:591; H.K.T., 12th October). Transylvania also experienced extreme heat in August of **1841** causing severe damage to the crops noted *Mihály Király*, a Calvinist pastor (*Réthly*, 1998m:1010). In the following year, the month of August in **1842** also brought drought to the Highlands and the Plain, with wells drying up and grazing-lands desiccated due to the lack of precipitation noted the Nemzeti Újság (National Paper) (*Réthly*, 1998m:636; N.Ú., 10th September). Both the Highlands and Transylvania had a very rainy August in **1845**, and both regions experienced floods (*Réthly*, 1998m:676; N.Ú., 25th August and 5th September), while late summer in **1850** was dry, as recorded in the Plain (*Réthly*, 1998m:715).

According to the averages of the Budapest time series the precipitation rates in August fluctuated a great deal from decade to decade. The decades of the 1860s, 1890s, 1900s, and also the 1940s were extremely dry while late summers in the 1850s, 1880s and 1930s brought wet weather. Since the 1950s the months of August have remained wet.

4.8.3. August Climate Change Trends over the Centuries

Temperature

The diagram of the 50-year temperature averages based on the climate history reconstruction reveal variations on a one hundred year scale. This historical time series shows a slight dominance of warm late summers. The only 50-year average with below average temperatures dates from the second half of the 16th century, but is based on so little data that it can be ignored. The first peak of the fluctuating warming trend occurred in the second half of the 17th century, while the relative decrease in the first half of the 18th century leads into the steady high temperature average in the second half of the 18th, and the first half of the 19th century. The 50-year temperature averages from the Budapest instrument based time series show a stronger cooling trend from the mid-19th century until the mid-20th century, while the August months in the second half of our century turned warmer.

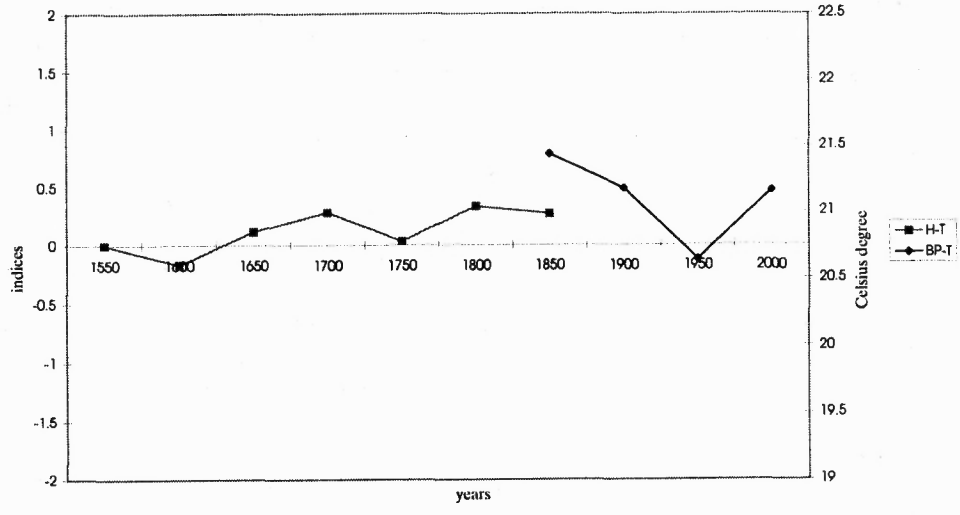
Precipitation

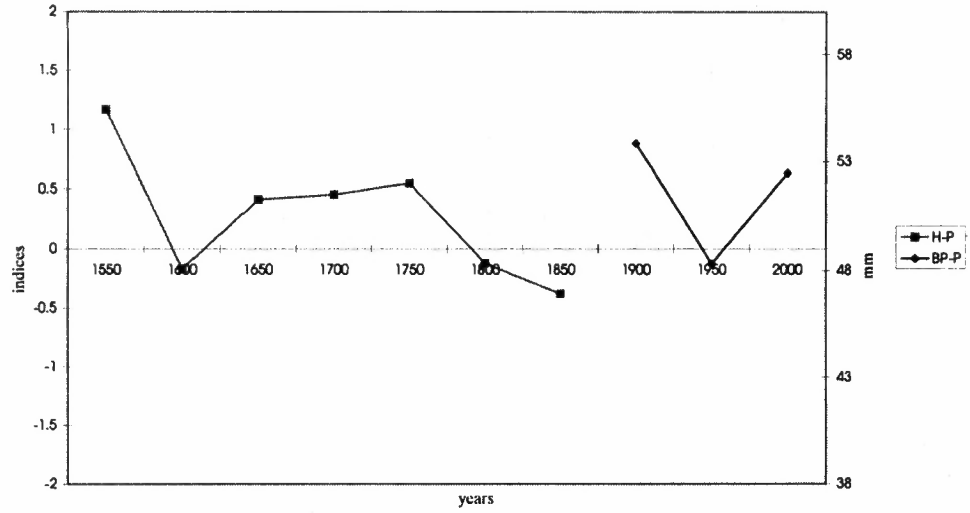
The 50-year averages based on the climate history precipitation indexes show the dominance of wet August months from the early 17th until the mid-18th century, again disregarding the flimsy data from the 16th century. It is easy to follow the trend of late summers becoming drier in the second half of the 18th and the first half of the 19th century. According to the 50-year averages of the Budapest precipitation time series the drying process which started in the mid-18th century continued until the mid-20th century, while the August months in the second half of our century turned again much wetter.

Climate Change Characteristics

Augusts remained mostly warm and slightly wet from the turn of the 17th until the mid-18th century. Late summers continued to be warm without surplus precipitation in the second half of the 18th and first half of the 19th century. The 50-year average of the Budapest time series show that the temperature and precipitation levels moved in unison, with the cooling trend accompanied by a drop in precipitation until the mid-20th century, with subsequent Augusts becoming warmer accompanied by a rise in precipitation levels.

Figure 27 *August temperature and precipitation 50-year averages over the decades from the 16th century until today. The first diagram (1500-1850) is based on the time series of a history based climate reconstruction, while the second diagram is based on the time series for instrument observations from the Budapest observatory (1780-1996)*





4.9. September

4.9.1. September Temperature Anomalies and Medium Term Trends

There is so little historical climate information available regarding average temperatures in September prior to the 17th century, that it is impossible to determine any trends for that timeframe. There is only one temperature anomaly known to us, from September **1551** when *Lestár Gyulafy* wrote in his chronicle that "it was so cold that it would not have been colder at Christmas either" (*Réthly*, 1962:78; *Gyulafy*, 1893:116).

The temperatures in the early autumns were quite stable from the second third of the 17th century until the mid-19th century, with very few anomalies.

The Saxon Chronicles reported that September of **1618** was so hot that spring crops were destroyed in Transylvania (*Réthly*, 1962:138; *Bielz*, 1862-63:39). **1639** went by with warm and dry weather in Transylvania (*Réthly*, 1962:172; *Haller*, 1862:58). *György Czegei Vass* recorded cold weather with some white frost for Transylvania in September of **1685** (*Réthly*, 1962:342).

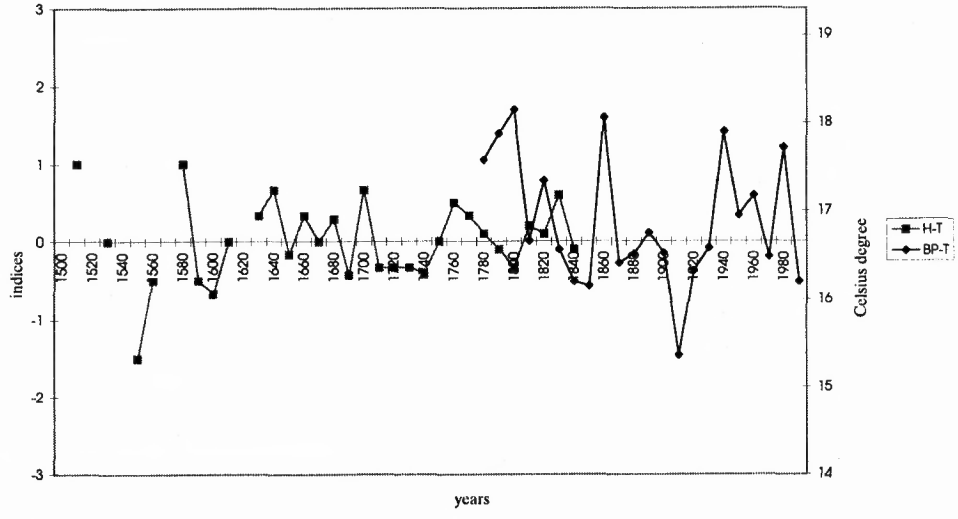
Andreas Loew wrote in his weather diary that September **1701** brought unusually warm and dry weather to Transdanubia (*Réthly*, 1970:27; *Sydenham*, 1763:297). It was also *Loew* that noted a fine, warm and mostly dry September of **1703** in Transdanubia (*Réthly*, 1970:32; *Sydenham*, 1763:301). Early autumn in September **1705** brought cool and rainy weather to Transdanubia (*Réthly*, 1962:36; *Sydenham*, 1763:312). However the same month in **1708** was hot and dry (*Réthly*, 1962:44; *Sydenham*, 1763:334-335). Father *István Körtvélyesi Jr.* wrote in his diary that September of **1770** brought sweltering heat to the Highlands (*Réthly*, 1970:502). Early autumn of **1781** was hot and dry in

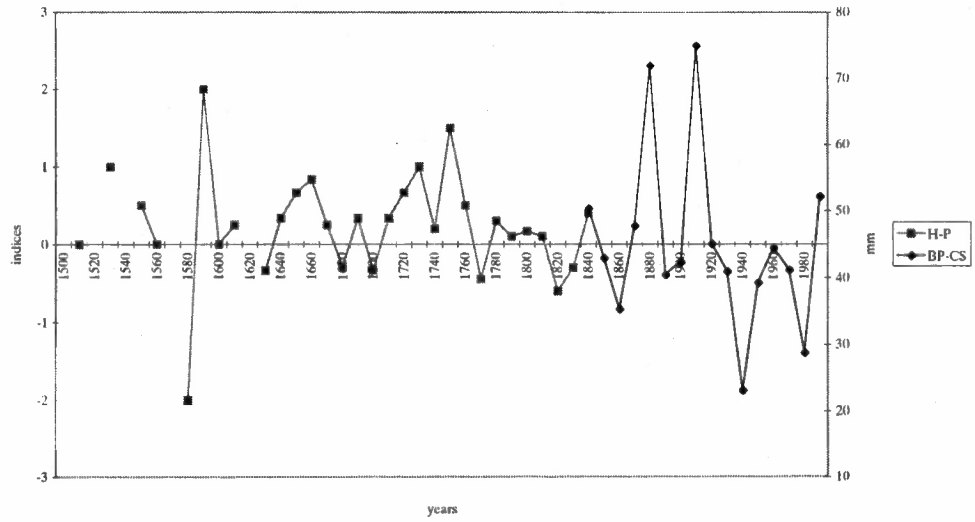
the Highlands and Transdanubia according to the 'Magyar Hírmondó' (Hungarian Messenger), while September of **1797** was extremely warm in the Plain (*Réthly*, 1970:442; M.H., 5th December).

The Pest-Buda correspondent of 'Pressburger Zeitung' reported September **1834** to be so hot and dry that wells and streams dried up (*Réthly*, 1998m:489; P.Z., 8th November). *Gábor Ecsedy*, a Calvinist pastor wrote in his diary that the Plain had an unusually warm September in **1838** (*Réthly*, 1998m:1130).

The averages of the Budapest temperature time series over the decades show that there was a strong cooling trend in the middle third of the 19th century, coldest in the 1840s and 1850s. After the unusually warm decade of the 1860s, there was another cooling trend reaching its coldest period in the 1910s. Beginning in the second third of the 20th century, the September months turned warmer while exhibiting significant fluctuations,

Figure 28 *September temperature and precipitation 10-year averages over the decades from the 16th century until today. The first diagram (1500-1850) is based on the time series of a history based climate reconstruction, while the second diagram is based on the time series for instrument observations from the Budapest observatory (1780-1996)*





4.9.2. September Precipitation Anomalies and Medium Term Trends

While we have data indicating anomalies towards both extremes during the 16th century, the overall data is far too sparse to enable us to outline any climate trend for the period. *Sebestyén Borsos* reported in his chronicle that the drought-ridden summer of **1580** was followed by a dry September in Transylvania (*Réthly*, 1962:96; *Borsos*, 1855:25). It was noted in *Istvánfi*'s chronicle that the royal troops could not travel on the sloppy roads in September of **1596** (*Réthly*, 1962:107; *Istvánfi*, 1867-71:769). *Istvánfi* also noted that the siege of Szigetvár was delayed by the rainy weather in **1597** (*Réthly*, 1962:108; *Istvánfi*, 1867-71:788).

The September months of the 17th century show a slight precipitation surplus, nevertheless there were precipitation anomalies of both extremes during the century. Transylvanian sources indicate that it was so dry in September **1639** that it was impossible to plant crops (*Réthly*, 1962:161; *Haller*, 1862:58). Early autumn of **1644** brought warm and dry weather to the Highlands (*Réthly*, 1962:172; *Haller*, 1862:95). The dry period of September **1686** delayed autumn planting in Transylvania, wrote *György Czegei Vass* (*Réthly*, 1962:342). *György Czegei Vass* reported that Transylvania had such a dry September in **1692** that it precluded ploughing (*Réthly*, 1962:347). According to *Raygeri*'s observations September of **1695** brought frequent rains to the Highlands (*Réthly*, 1962:172; *Sydenham*, 1763:172).

Septembers in the first two thirds of the 18th century turned much wetter. *Dr. Loew* observed that early autumn of **1701** brought warm and dry weather to Transdanubia (*Réthly*, 1970:27; *Sydenham*, 1763:297). This region had a cool and rainy September in **1705** (*Réthly*, 1970:36; *Sydenham*, 1763:312). *Loew* noted warm and dry weather again in the Early autumn of **1708** (*Réthly*, 1970:44; *Sydenham*, 1763:334-335). *György*

Buchholtz recorded that rain was frequent in the Highlands in the early autumn of **1717** (*Réthly*, 1970:69; Sammlung, 1720:414), while *János Ádám Reimann* noted the same in September of **1720** (*Réthly*, 1970:87; Sammlung, 1720:414). On the other hand, *György Buchholtz* noted that September of **1726** was so dry in the Highlands that it precluded the planting of crops (*Réthly*, 1970:119). The following year *Buchholtz* reported in September of **1727** that the corn germinated in the fields due to the overabundance of rain (*Réthly*, 1970:124; Nachrichten, 1727:539). September of **1729** was laconically characterised by *György Buchholtz* to be a 'rainy month' (*Réthly*, 1970:134; Nachrichten, 1729:535). Notes from the Highlands said that the grapes started to split on the vine due to the heavy rains in September of **1751,** so the harvest had to be started early (*Réthly*, 1970:187; *Baróti*, 1893-96:533). Due to the numerous rainy days in September of **1758,** the autumn planting could not start until St. Michael's Day (29 September) (*Réthly*, 1970:196; *Cserei Gy.,* 1875:325-326,341). Father *István Körtvélyesi Jr.* noted that the grapes started to rot on the vine due to frequent rains in September of **1768** (*Réthly*, 1970:501).

The precipitation averages by decade for the last third of the 18th century indicate a very stable period however these statistical averages mask the reality that the frequency of precipitation in September increased over the last three-quarters of the period covered by our climate history reconstruction. Father *István Körtvélyesi Jr.* wrote that the Highlands had constant early autumn drought in September of **1776** (*Réthly*, 1970:506). *Körtvélyesi* also reported dry weather in the Highlands in September of **1779** (*Réthly*, 1970:506). The 'Magyar Hírmondó' (Hungarian Messenger) wrote that the grapes started to rot again in September **1780** due to the constant rains in the Highlands (*Réthly*, 1970:273; M.H., 14th October). The correspondents from Transdanubia and the Highlands of the same paper reported that early autumn the following year brought heat and drought to those regions. In September **1782** the small arm of the Danube below Pest-Buda dried up completely between Transdanubia and the Highlands due to the drought (*Réthly*, 1970:297; M.H., 21st September). The September rains in **1794** caused serious damage to the vineyards of the Tokaj region in the Highlands (*Réthly*, 1970:417; M.H., 14th October). The 'Pressburger Zeitung' reported that Transdanubia received constant rain in September of **1801** with the exception of only a few days of dry weather (*Réthly*, 1998m:11; P.Z., 6th October). The dry September weather in **1802** was not beneficial to the grape harvest in Buda, wrote 'Vereinigte Ofner and Pester Zeitung' (*Réthly*, 1998m:19; V.O.P.Z., 23rd September and 7th October). September of **1803** was dry again the following year in Hungary according to various newspapers (*Réthly*, 1998m:33). It was noted in the Historia Domus of the Franciscan Monastery in Kecskemét that the whole month of September in **1809** was rainy in the Plain (*Réthly*, 1998m:80), while the 'Hazai és Külföldi Tudósítások' (Local and Foreign Reports) published an article about a drought in Transdanubia and the Plain in the early autumn of **1810**, making it impossible to plough or plant (*Réthly*, 1998m:90; H.K.T., 19th September). September of the following year was dry again and farmers with livestock in the Highlands had serious difficulty providing the animals with enough fodder in **1811** (*Réthly*, 1998m:103). In **1813** the 'Pressburger Zeitung'

wrote about extensive rainfalls causing serious floods in the country (*Réthly*, 1998m:136; P.Z., 17th and 24th September, 5th October). The Highlands again received a lot of rain in September of **1818**, wrote *József Ásvay Jókai* in his diary (*Réthly*, 1998m:267). The Plain had dry weather in the early autumn of **1824** (*Réthly*, 1998m:347; *Auer*, 1952:195). The newspapers reported in detail about the unusually wet weather in **1833**, causing the grapes to start rotting on the vine, and the rivers in the Highlands to flood in several places (*Réthly*, 1998m:475; H.K.T., 5th and 9th October). The following year, September **1834,** brought a long drought, causing the water level of the Danube to fall so low that there were shallows in the riverbed (*Réthly*, 1998m:486; H.K.T., 11th October). The 'Erdélyi Híradó' (Transylvanian Messenger) reported that the September weather in **1837** was very dry in the Plain (*Réthly*, 1998m:519; E.H. 22nd October).

The Budapest precipitation time series shows that precipitation was very different in the 19th century, with a notable minimum in the 1860s and 1890s, and a notable maximum in the 1880s. The 20th century started with high precipitation rates referred to as unsurpassable and it led practically straight to the extremely dry decade of the 1940s. The quantity of early-autumn precipitation rose slightly in the 1950s and 1960s, but a new trend of decreasing precipitation began in the 1970s.

4.9.3. September Climate Change Trends over the Centuries

Temperature

The graph of the 50-year averages calculated from the temperature indexes of the climate history reconstruction, with slight fluctuations, closely follows the '0' value or 'reference average' value. This indicates that the temperatures within the studied period tended to be average in nature overall, with the exception of the 16th century period for which there is insufficient reliable data available. The Budapest time series based on instrument measurements shows a higher proportion of significant temperature changes than that observed for the period analysed using historical reconstruction methods. In fact there was a steady and significant cooling process from the turn of the 19th until the middle of the 20th century, followed by a strong warming trend in the second half of our century.

Precipitation

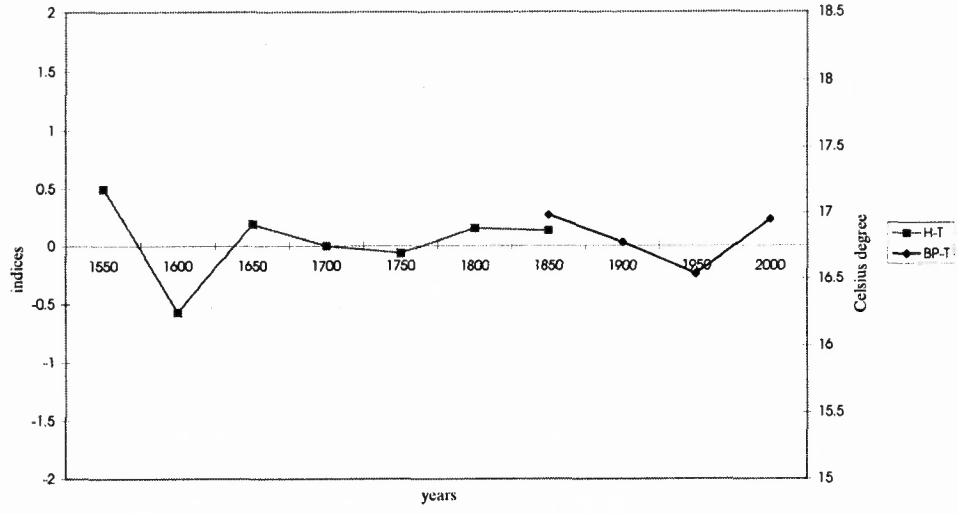
The time series showing the 50-year averages based on climate history reconstruction data is quite similar to that for temperature as once again only slight fluctuations are observed during the three and a half centuries analysed. But in the case of the precipitation time series there is overall slight precipitation surplus for the period. It is worth noting that the slight drying trend that started in the mid-18th century, as indicat-

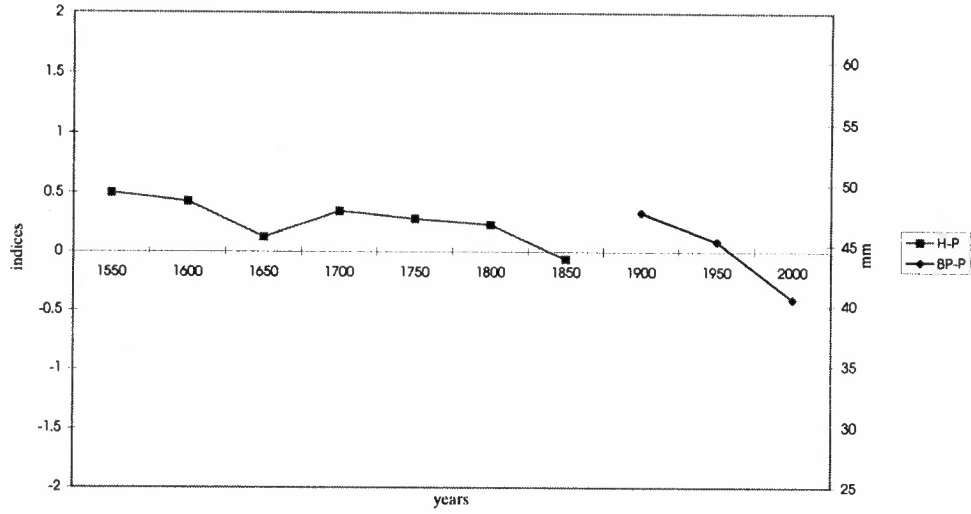
ed by the historical reconstruction, is shown to have continued to the present day according to the Budapest data gleaned from instrument based measurements.

Climate Change Characteristics

While we are again forced to exclude from the analysis that period of the 16th century which is poorly documented, it can be clearly seen that most of the September months from the turn of the 17th century until the second half of the 18th century exhibited stable temperatures and a slight surplus of precipitation. From the beginning of the 19th century, a cooling trend begins, lasting until the mid-20th century, which is accompanied by a drying trend. The subsequent warming trend in the second half of our century is accompanied by a continuation of the tendency towards drier weather in evidence now for the past two centuries.

Figure 29 *September temperature and precipitation 50-year averages over the decades from the 16th century until today. The first diagram (1500-1850) is based on the time series of a history based climate reconstruction, while the second diagram is based on the time series for instrument observations from the Budapest observatory (1780-1996)*





4.10. October

4.10.1. October Temperature Anomalies and Medium Term Trends

The October temperature time series based on the climate history reconstruction reflects considerable stability, with few fluctuations away from our reference average month temperature or '0' value. Further support for this observation is reflected by the fact that there are very few anomalies in the October temperature time series.

Turkish historians recorded that Turkish troops returning home after the unsuccessful siege of Vienna in October **1529** suffered considerably due to the cold, wet weather in Transdanubia (*Réthly*, 1962:66; *Thúry*, 1893:341-344). On the other hand the trees were blossoming in October of **1553** due to the warm weather (*Réthly*, 1962:79; *Hain D.*, 1853-54:8). *Zsigmond Torda* wrote in his diary that October of **1562** was dry and warm in the Highlands (*Réthly*, 1962:266).

We know of one single temperature anomaly from the 17th century. Transylvanian sources reported that the cold winter weather had already started in October of **1614** (*Réthly*, 1962:133; *Hain D.*, 1853-54:16).

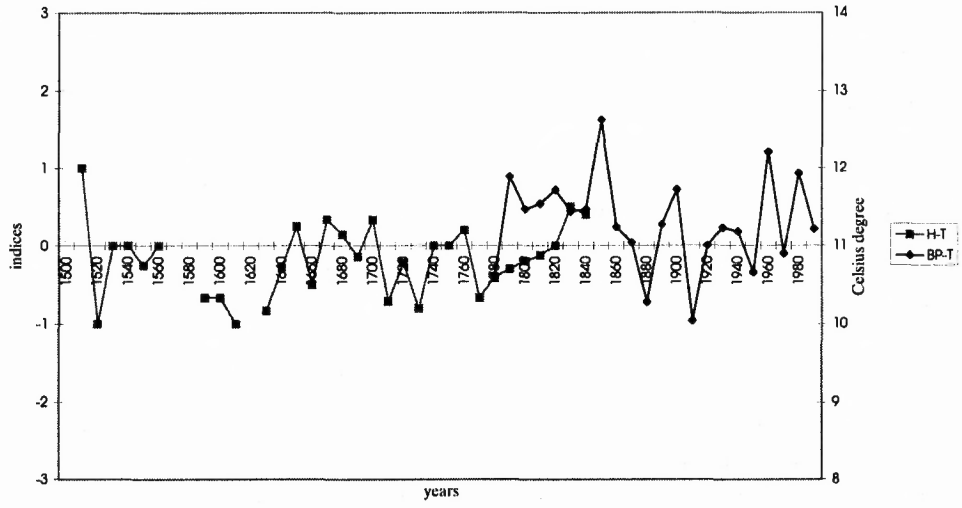
Transdanubia had a heat wave unlike anything previously experienced in October of **1701**, wrote *Andreas Loew* (*Réthly*, 1970:27; *Sydenham*, 1763:297). The Fauth Chronicle reported that October of **1716** brought cold and frost to Transdanubia, and in some areas it even snowed (*Réthly*, 1970:65). According to *János Ádám Reimann*'s meteorological notes, the Highlands had a cold October in **1730** with frequent snowfalls (*Réthly*, 1970:137; Nachrichten, 1730:1383). The 'Pressburger Zeitung' reported cold

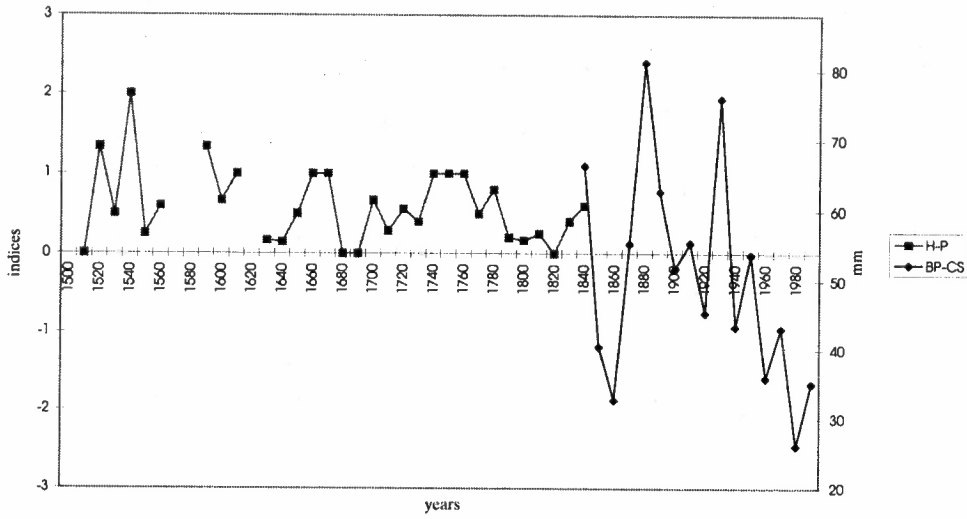
and snowy weather in the Highlands in October of **1775** (*Réthly*, 1970:243; P.Z. 3rd January, 1776).

The Pest-Buda correspondent of the 'Hazai és Külföldi Tudósítások' (Local and Foreign Reports) wrote that the weather was pleasant and warm in October of **1819** (*Réthly*, 1998m:278; H.K.T., 13th November). The same month in **1825** brought cold and rainy weather in the Highlands (*Réthly*, 1998m:358; H.K.T., 14th December). *Antal Karácsony* noted in his diary that it was warm in Transdanubia in October **1841**, when the fruit trees blossomed for the second time that year, and there was even a second crop of strawberries (*Réthly*, 1998m:1328). 'Erdélyi Híradó' (Transylvanian Messenger) published the news that the warm weather in October **1846** resulted in the harvesting of a second crop of cherries in Buda (*Réthly*, 1998m:689; E.H., 1st November).

The October months in mid-19th century were warm, as shown by the data of the Budapest temperature time series, and the high-point of the 1950s decade has not since been exceeded. Nevertheless a period of fluctuations with an overall cooling trend began in the second half of the 18th century, reaching its lowest points in the 1880s and 1910s. Mid-autumn turned warmer again from the middle of the 20th century, with notable warm periods in the 1960s and 1980s.

Figure 30 *October temperature and precipitation 10-year averages over the decades from the 16th century until today. The first diagram (1500-1850) is based on the time series of a history based climate reconstruction, while the second diagram is based on the time series for instrument observations from the Budapest observatory (1780-1996)*





4.10.2. October Precipitation Anomalies and Medium Term Trends

The October months of the 16th century were mostly wet according to the few sources available. Turkish sources tell us about unusually cold, wet weather in October **1529**, and that there were extensive spates in Transdanubia (*Réthly*, 1962:66; *Thúry*, 1893:341). *Istvánfi*'s Chronicle recorded that the constants rains and muddy roads caused delay in the troop movements of *Suleiman I* returning home from Buda through Transdanubia in October **1543** (*Réthly*, 1962:73; *Istvánfi*, 1867-71:310). *Zsigmond Torda* noted in his diary that the Highlands had dry warm weather in October **1562** (*Réthly*, 1962:266). The month of October two years later in **1564**, again according to *Torda*'s notes, brought constant rain to the Highlands (*Réthly*, 1962:267). Palatine *István Illésházy* recorded in October **1598** that the constant rains prevented the movement of the Turkish troops in the Plain and in Transdanubia (*Réthly*, 1962:109; *Illésházy*, 1863:62).

Precipitation increased in October months in the middle third of the 17th century. Transylvania experienced a very dry period in October **1642**, which prevented fall planting (*Réthly*, 1962:168; *Haller*, 1862:80). Saxon sources reported that October of **1649** was so rainy in Transylvania that it was impossible to drive on the muddy roads (*Réthly*, 1962:178; *Krauss*, 1862:I.179). *Count Mihály Teleki* wrote in a letter that Transylvania was hit by such heavy rains in October **1678** that the Turkish envoys postponed their return due to the spates (*Réthly*, 1962:218; *Teleki*, 1905-26:VII.559).

There was a decrease in precipitation in the October months of last decades of the 17th century. October **1686** was very dry in Transylvania, wrote *György Czegei Vass* (*Réthly*, 1962:342).

Rainy October months dominated the whole of the 18th century. The Payr Chronicle reported that October of **1700** brought hopelessly rainy weather in Transdanubia (*Réthly*, 1962:262; *Payr*, 1942:92-93). The same month nine years later in **1709** again brought an abundance of rain to the Plain (*Réthly*, 1970:49; *Cserey M.*, 1852:420). *János Ádám Reimann* noted that it rained nearly every day in the Highlands in October **1728** (*Réthly*, 1970:130; Nachrichten, 1728:1439. Both the Bruckner Chronicle and Father *István Körtvélyesi Jr.*, a Calvinist pastor, related that frequent rains fell in Transdanubia and the Highlands in October **1761** (*Réthly*, 1970:200, 500). The Historia Domus of the Franciscan Monastery in Gyöngyös recorded that a rainy October in **1770** caused a delay in the harvesting of the grapes in the Highlands (*Réthly*, 1970:473). 'Pressburger Zeitung' reported in October **1775** that the Highlands had cold weather and a lot of snow. The thick snow cover caused a lot of damage to the fruit gardens and forests (*Réthly*, 1970:243; P.Z., 3rd January, 1776). A year later Father *István Körtvélyesi Jr.* wrote that October brought a severe drought to the Highlands (*Réthly*, 1970:505). *Sámual Benkő*'s notes indicate that October of **1785** was rainy and windy in the Highlands (*Réthly*, 1970:527).

Precipitation rates for the months of October decreased somewhat in the first half of the 19th century. The Highlands had an extremely dry October in **1802**, wrote the 'Pressburger Zeitung', when wells and rivers dried up and there were frequent forest fires as well (*Réthly*, 1998m:20; P.Z., 15th October). There were rains across the country in October of **1808** causing heavy floods according to the 'Hazai és Külföldi Tudósítások' (Local and Foreign Reports) (*Réthly*, 1998m:64; H.K.T., 29th October). A year later in **1809** the rainy weather of the previous October returned once again (*Réthly*, 1998m:83). The Pest-Buda correspondent of the 'Hazai és Külföldi Tudósítások' (Local and Foreign Reports) wrote that the weather in October of **1823** was very dry (*Réthly*, 1998m:335; H.K.T., 29th October). October of **1825** brought cold and rainy weather according to the Highlands-correspondent of the same paper, and the roads were made impassable to traffic (*Réthly*, 1998m:358; H.K.T. 14th December). As a result of dry October weather in **1832,** the Danube reached its lowest water levels ever, according to news reported by the Highlands-correspondent of the 'Pressburger Zeitung' (*Réthly*, 1998m:463; P.Z., 6th November). 'Vereinigte Ofner und Pester Zeitung' reported constant rainfall in the Plain in October **1840** (*Réthly*, 1998m:605; V.O.P.Z., 13th December). *Gábor Ecsedy*, a Calvinist pastor, wrote in his diary that the Plain saw rains mostly in the first and last third of October in **1847** (*Réthly*, 1998m:1180).

The averages of the Budapest precipitation time series by decade show that after major fluctuations in the middle of the 19th century the October months became mostly wet from the 1880s until the 1930s. This trend reversed in the mid-20th century with the trend towards drier Octobers becoming particularly notable beginning in the 1960s.

4.10.3. October Climate Change Characteristics over the Centuries

Temperature

The temperature time series based on the climate history reconstruction is fairly stable and shows the dominance of October months that are slightly cooler than the average. The exceptions to this overall trend were the cold period in the first half of the 17th century, and the warm period in the first half of the 19th century. The Budapest time series based on data collected with weather instruments shows a long period of cooler weather from the mid-19th until the mid-20th century followed by a warming trend in the second half of the century.

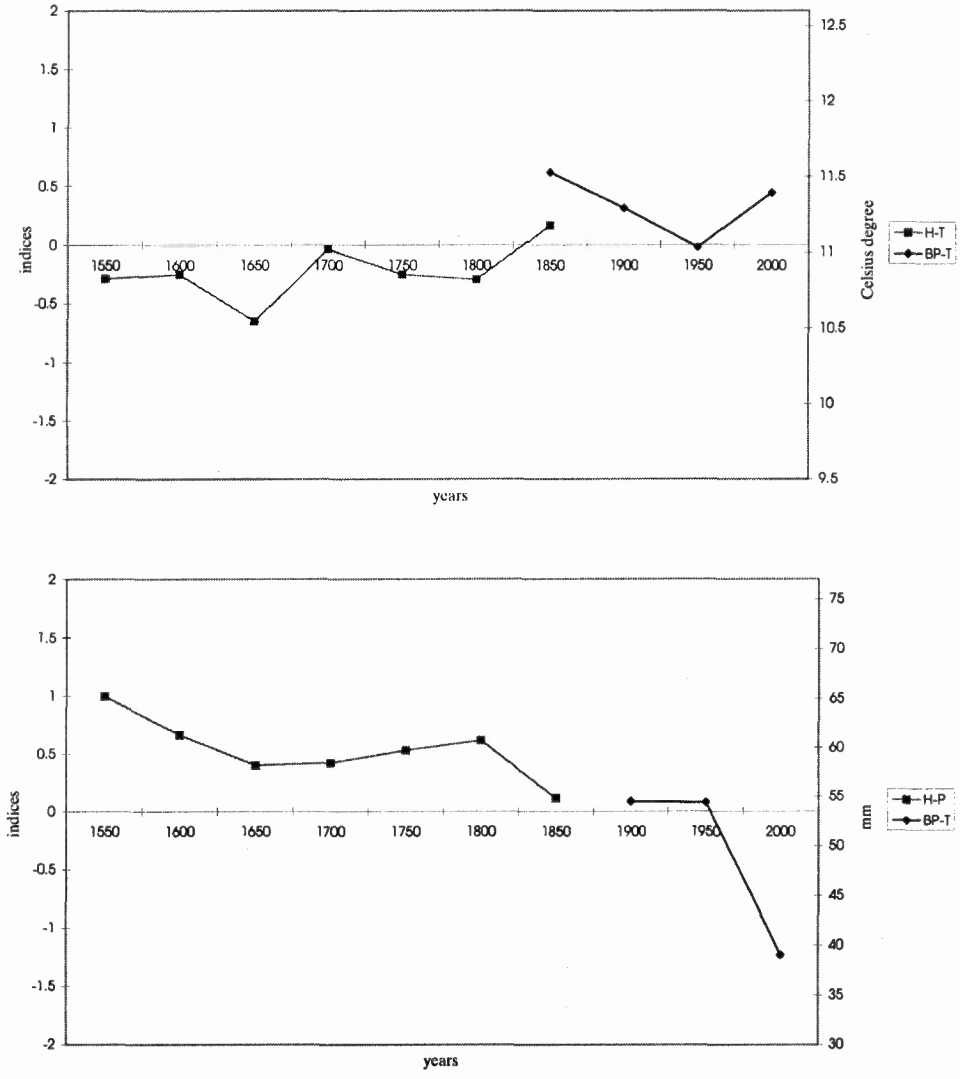
Precipitation

The October precipitation time series based on a reconstructed climate history showed a significant and notable precipitation surplus for the duration of the Little Ice Age, with the only exception being a drier period in the first half of the 19th century. The Budapest instrument based measurements show that October precipitation rates did not change much in the second half of the 19th and the first half of the 20th century, while in the second half of our century a definite tendency towards drier Octobers is evident.

Climate Change Characteristics

The dominant character of October months during the Little Ice Age was cool and wet weather until the end of the 18th century. The cooling process from the mid-19th through the mid-20th century was not accompanied by a significant change in precipitation rates, while the warmer period that started in the second half of our century did bring with it a significant drying trend.

Figure 31 *September temperature and precipitation 50-year averages over the decades from the 16th century until today. The first diagram (1500-1850) is based on the time series of a history based climate reconstruction, while the second diagram is based on the time series for instrument observations from the Budapest observatory (1780-1996)*



4.11. November

4.11.1. November Temperature Anomalies and Medium Term Trends

One can venture to conclude, despite the uneven distribution of the meagre sources available to us for the period, that the November weather was mostly cold from the beginning of the 16th until the middle of the 17th century, and that this was particularly true at the turn of the 17th century. *Istvánfi* wrote in his chronicle that unusually cold weather in November of **1595** caused a lot of suffering among both the Turkish and the Royal troops (*Réthly*, 1962:106; *Istvánfi*, 1867-71:754). Turkish historians wrote that the winter weather had already begun in October **1597**, and that it was snowing in November (*Réthly*, 1962:113; *Karácson*, 1916:269). Reports from Sopron indicate that Transdanubia was already experiencing winter weather, including snow, in November of **1600** (*Réthly*, 1962:113). It was recorded in the Payr Chronicle that the vintage started as late as November in **1632**, but the grapes were frozen on the vine stalks (*Réthly*, 1962:152; *Payr*, 1942:24). Saxon Chronicles reported that it was snowing in November of **1634** and that the cold weather was as unbearable as one might normally expect in January (*Réthly*, 1962:153; *Krauss*, 1862:I.117).

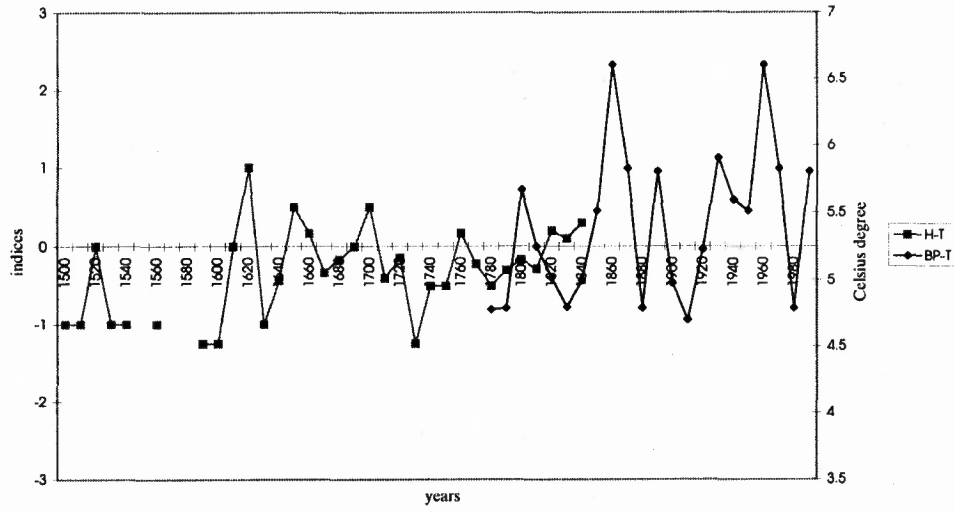
The average November temperatures by decade paint a stable picture from the second half of the 17th until the end of the 18th century, and the number of temperature anomalies was low during this period of one hundred and fifty years. It snowed in Transylvania early in November of **1686** and the resultant useful sledge-road remained in good condition until Christmas, wrote *György Czegei Vass* (*Réthly*, 1962:342). Prince *Imre Thököly* entered in his war log that November of **1693** brought pleasant spring-like weather to the Plain (*Réthly*, 1962:331). Transdanubia experienced unusually mild weather in November of **1708**, according to *Andreas Loew*'s notes (*Réthly*, 1970:45; *Sydenham*, 1763:334-335). *János Ádám Reimann* published an article in the scientific magazine 'Nachrichten...' in Erfurt stating that the first half of November was cold in the Highlands in **1730**, while it snowed in the second half (*Réthly*, 1970:137; Nachrichten, 1730:1439). 'Magyar Hírmondó' (Hungarian Messenger) wrote that the weather in November of **1782** was so cold in Hungary that there was already ice drifting on the Danube (*Réthly*, 1970:299; M.H., 7th December).

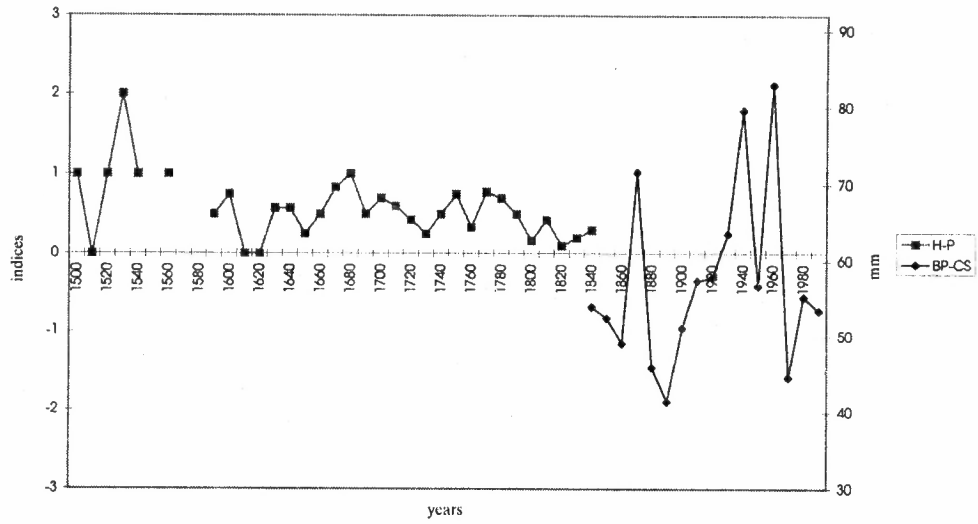
Based on the climate history data, one concludes that beginning from the first half of the 18th century, the average November temperature rose, and the number of positive temperature anomalies grew as well. Thanks to the warm weather in November of **1811** there were ripe strawberry fields in Transdanubia and the grapes sprouted again on the vines, according to the Bruckner Chronicle (Réthly, 1998m:106). The Pest-Buda correspondent wrote for the 'Hazai és Külföldi Tudósítások' (Local and Foreign Reports) that the weather was mild in November of **1821** and that the livestock could be driven to pasture until early December (*Réthly*, 1998m:306; H.K.T., 19th December). In **1829** the newspapers carried reports about early November snow falling across the country. They also reported that the second half of the month was extremely cold, that

there were snowstorms, and that ice floes were drifting down the Danube at Pest-Buda by the 20th of November (*Réthly*, 1998m:411; H.K.T., 18th and 21st November).

The data from the Budapest temperature time series indicate that most of the November months in the middle third of the 19th century were warm, particularly during the 1850s and 1870s. There was a transitory cooling trend at the turn of the 20th century, while the November weather turned milder from the 1930s through the 1970s. The average November temperature of the 1980s and 1990s has been more reminiscent of late autumn than early winter.

Figure 32 *November temperature and precipitation 10-year averages over the decades from the 16th century until today. The first diagram (1500-1850) is based on the time series of a history based climate reconstruction, while the second diagram is based on the time series for instrument observations from the Budapest observatory (1780-1996)*





4.11.2. November Precipitation Anomalies and Medium Term Trends

The time series based on climate history reconstruction shows a steady surplus of precipitation in the November months from the early 16th until the mid-19th century.

The Istvánfi Chronicle reported that constant cold rains caused difficulties in the movement of the Turkish and the Royal troops at Buda in November of **1530** (*Réthly*, 1962:66; *Istvánfi*. 1867-71:202).

Saxon sources indicate that there was plenty of rain in November of **1641** and it was impossible to drive on the roads (*Réthly*, 1962:165; *Haller*, 1862:73). Similarly weather in Transylvania in November **1649**, also according to Saxon sources, caused disruption to road traffic as well as mud slides in several areas (*Réthly*, 1962:178; *Krauss*, 1862:I.179). *Amrus Keczer* entered in his diary that the Highlands experienced constant rain in November of **1665** making road travel difficult and causing spates in several places (*Réthly*, 1962:283). *György Czegei Vass* recorded that Transylvania had rainy, muddy conditions in November of **1689** (*Réthly*, 1962:344).

The Payr Chronicle reported that most of the autumn was unusually wet in Transdanubia in the year of **1700**, with constant rain from St. Michael's Day (September 29) until Advent (November 28) (*Réthly*, 1962:262; *Payr*, 1942:92-93). November of **1709** also brought plenty of rain according to Transylvanian sources (*Réthly*, 1970:29; *Cserei M.*, 1852:420). This region had rainy, foggy, cloudy weather in November of **1764** (*Réthly*, 1970:212; *Cserei Gy.*, 1875:389). Father *István Körtvélyesi Jr.* recorded that it rained constantly during November of **1773** in the Highlands (*Réthly*, 1970:503), and that similar conditions in the same region in November **1775**, made the vintage more difficult (*Réthly*, 1970:504). The 'Pressburger Zeitung' wrote that there were spates in the Highlands as a result November rains in **1779** (*Réthly*, 1970:260;

P.Z., 27th November and 11th December). November **1782** brought cold and extremely cold weather to the Highlands and the traffic was totally blocked by snow storms, according to the 'Magyar Hírmondó' (Hungarian Messenger) (*Réthly*, 1970:299; M.H., 13th November).

The Budapest instrument based precipitation time series shows that November precipitation in the second third of the 19th century was quite unstable and that there was a notable trend towards drier weather beginning with the 1880s, which continued until the beginning of the 20th century. November precipitation increased significantly in the middle third of the 20th century, most notably in the 1940s and 1960s, decreasing again from the 1970s on.

4.11.3. November Climate Change Trends over the Centuries

Temperature

The 50-year averages of the November temperature time series shows a dominance of cold November months from the beginning of the 16th until the middle of the 17th century. From the second half of the 17th until the middle of the 19th century, the average November temperature remained steady around the '0' value marking the reference average. The Budapest instrument based data results in a time series indicating that Novembers became significantly colder during the 19th century. From the turn of the 20th century there was a strong warming trend, which has continued until this day.

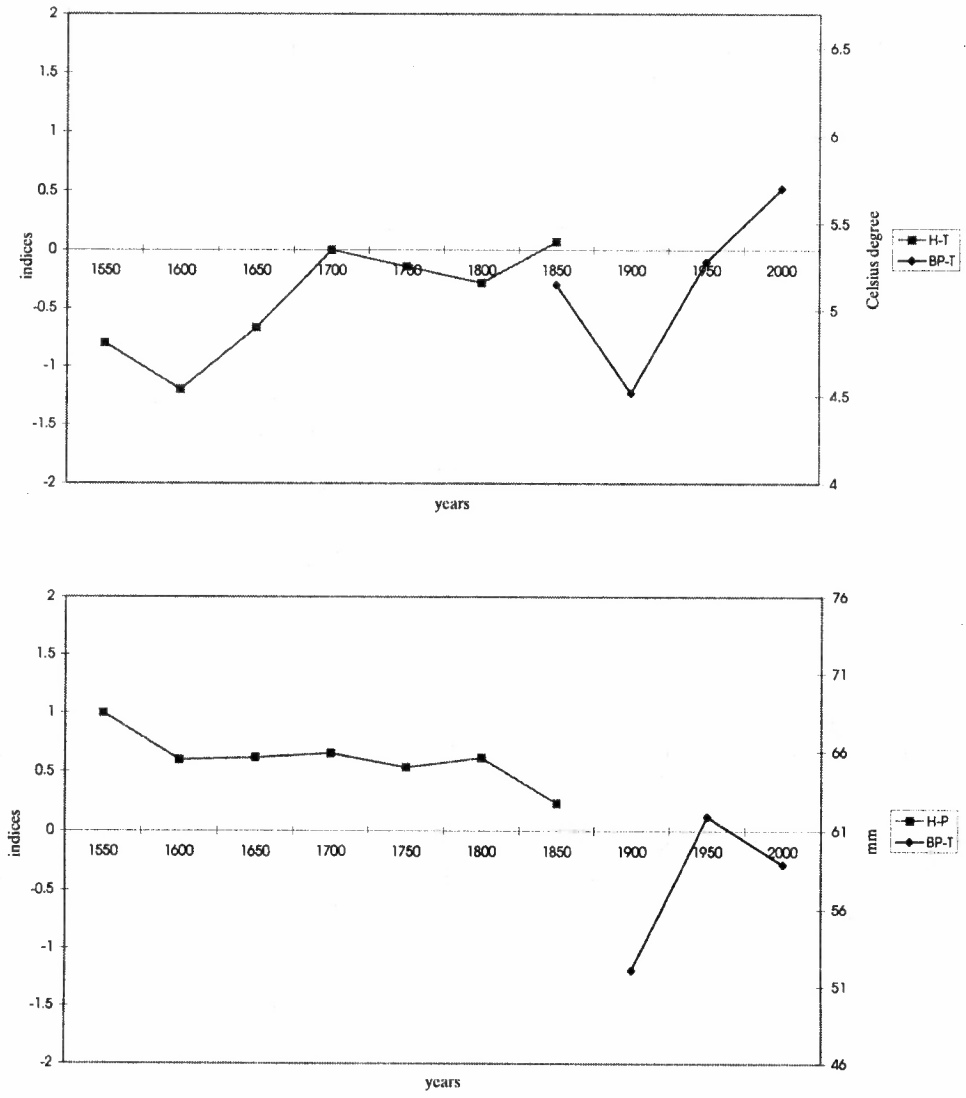
Precipitation

Precipitation levels were mostly positive during November months from the beginning of the 16th until the mid-19th century. A drying trend started to take shape at the turn of the 19th century, strengthening significantly in the second half of the century. Novembers turned wet again in the first half of the 20th century, and from the middle of the century the drying trend returned.

Climate Change Characteristics

Novembers were mostly cold and wet from the beginning of the 16th until the end of the 18th century. The November weather in the first half of the 19th century, while wet, was somewhat milder. According to the Budapest temperature time series, the steady warming period which started in the second half of the 19th century was accompanied by a rise in precipitation levels until the mid-20th century, after which precipitation decreased again throughout the second half of the century.

Figure 33 *November temperature and precipitation 50-year averages over the decades from the 16th century until today. The first diagram (1500-1850) is based on the time series of a history based climate reconstruction, while the second diagram is based on the time series for instrument observations from the Budapest observatory (1780-1996)*



Rácz, Lajos: Climate History of Hungary Since 16th Century: Past Present and Future.
Pécs: Centre for Regional Studies, 1999. 160 p.
Discussion Papers, No. 28.

4.12. December

4.12.1. December Temperature Anomalies and Medium Term Trends

As stated earlier, there are only a few sources of climate history related information available from the 16th century, so no definite climate change trend can be outlined for that timeframe. There are records available, however, regarding some temperature anomalies. *Count Tamás Nádasdy* wrote in his letter that the Danube froze between the Highlands and Transdanubia in December of **1538** due to the cold weather (*Réthly*, 1962:82-83; *Komáromy*, 1911:97). On the other hand, December of **1562** brought wet, warm weather to the Highlands, wrote *Zsigmond Torda* (*Réthly*, 1962:266). December weather a year later was again mild in the Highlands, reported *Gáspár Hain*, with the result that it was still possible plough just two weeks before Christmas (*Réthly*, 1962:86; *Hain G.,* 1910-13:100). It was so cold in December **1565** that all the rivers froze in Transylvania, wrote *Sebestyén Borsos* (*Réthly*, 1962:269). *Zsigmond Torda* noted that the whole month of December brought mild weather in **1567** (*Réthly*, 1962:269).

The average December temperatures in the decades of the 17th and 18th century were stable and the number of anomalies was remarkable low.

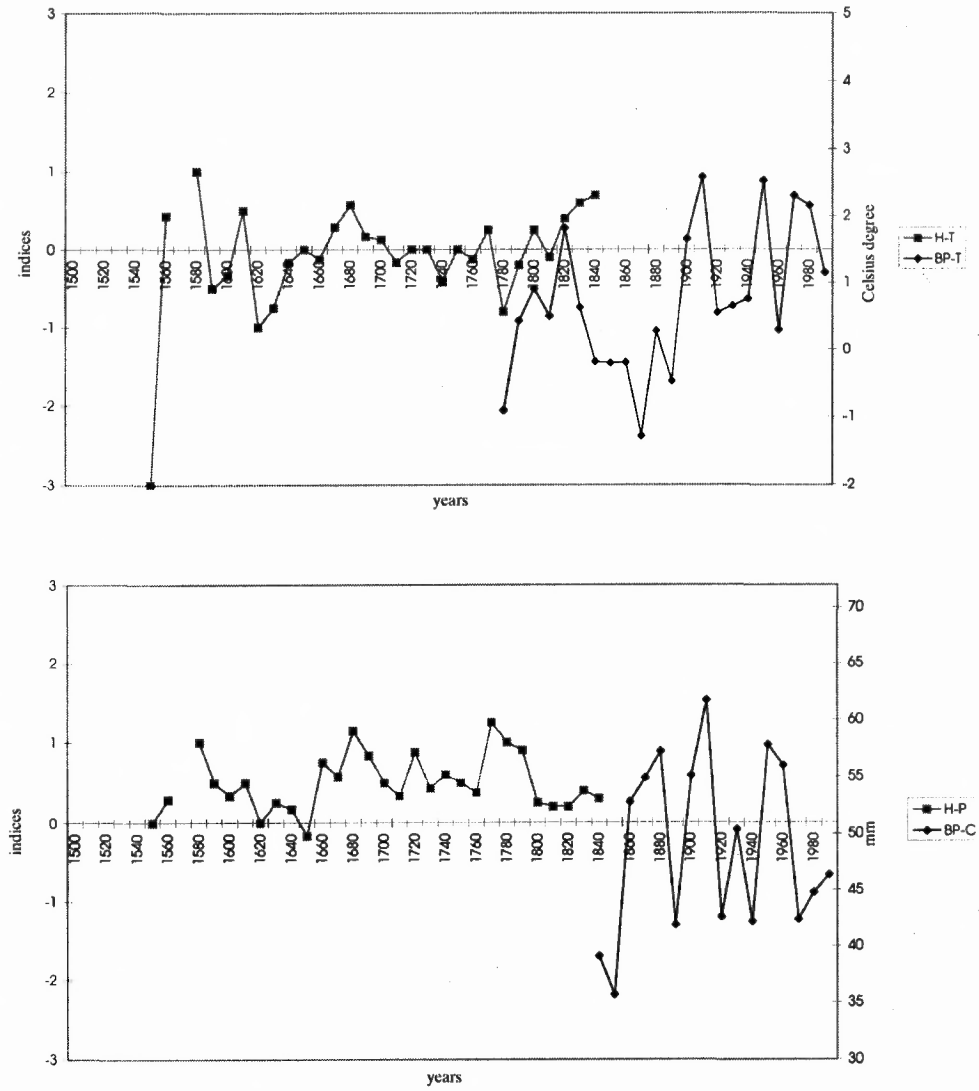
The Payr Chronicle reported that the weather was constantly warm in Transdanubia in December of **1612**, and that there were no frosts until New Year's eve (*Réthly*, 1962:131; *Payr*, 1942:11). Transylvania experienced such warm weather in December of **1641** that gardens and fields were in blossom (*Réthly*, 1962:165; *Krauss*, 1862:136). As a result of the autumn dry weather, autumn planting was possible in Transylvania only at the end of November in **1642**, but the December frosts caused a lot of damage to the crops (*Réthly*, 1962:168; *Haller*, 1862:81). *György Czegei Vass* recorded in his diary that December of **1684** brought such mild weather that was possible to plough and plant until Christmas (*Réthly*, 1962:341).

Albert Bielz's Saxon Chronicles note that the weather was extremely cold in Transylvania in December **1754** (*Réthly*, 1970:191; *Bielz*, 1862-63:65). This area had a dry, cold period in December of **1762**, with major frosts causing considerable damage to the recently sown crops that were left unprotected due to the lack of snow cover (*Réthly*, 1970:201-202; *Halmágyi*, 1906:41). The 'Pressburger Zeitung' reported that December of **1781** brought a severe cold period to Transylvania and the Plain, causing the River Temes to freeze from the surface all the way down to the riverbed (*Réthly*, 1970:286; P.Z., 12th January, 1782). The correspondents of various newspapers commented that December of **1788** was colder in every region of the country than it had ever been before, and that the Danube was already frozen solidly enough at Pest-Buda on the 20th of December to support the weight of heavy carts crossing the ice (*Réthly*, 1962:355-356; P.Z., 10th January, 1789; M.K., 10th January, 1789). According to *Sámuel Benkő*'s weather observations, December of **1799** also brought extremely cold weather to the Highlands (*Réthly*, 1970:534).

The averages of the December temperature indexes by decades in the first half of the 19th century show that the early-winter weather turned slightly milder. 'Pressburger Zeitung' wrote that the December weather was definitely spring-like in **1802** (*Réthly*, 1998m:20; P.Z., 7th January, 1803). Cold winter weather arrived in Transdanubia and the Plain early in December of **1812**, reported the 'Hazai és Külföldi Tudósítások' (Local and Foreign Reports), and at Pest-Buda traffic was already crossing the ice on the Danube, with temperatures at Buda reaching as low as –20 to -25 °C by the end of December. Due to the intense cold, wolves were sighted in the 'puszta' region of the Plain and many people froze to death (*Réthly*, 1998m:115; H.K.T., 30th December). The 'Pressburger Zeitung' reported that December of **1822** brought such cold weather that by the end of the month thick ice had formed on the Danube at Pest-Buda, again allowing the transport of goods across the ice (*Réthly*, 1998m:323; P.Z., 24th December and 5th January, 1823). December of **1825** passed with warm, spring-like weather, there were no frosts, the roads were covered with dry dust and the gardens and fields were in blossom (*Réthly*, 1998m:359; H.K.T., 31st December). According to 'Pressburger Zeitung', Transdanubia and the Plain experienced severe winter cold in December of **1829**, with temperatures of -14 °C recorded in Buda around Christmas (*Réthly*, 1998m:413; P.Z., 30th December). The Danube froze between Transdanubia and the Highlands during the cold December of **1840**, and temperatures dropped to the -17,5 – 20 °C range in Bratislava (G-Pressburg, H-Pozsony) during the period (*Réthly*, 1998m:606). *László Zlinszky* entered in his diary that the Plain experienced mild weather in December of **1841**, with the first frost coming as late as the last day of the month (*Réthly*, 1998m:939). December of **1843** was mild and rainy, according to *Gábor Ecsedy*'s records (*Réthly*, 1998m:1161).

The decade average temperatures for December according to the Budapest time series show that the milder weather at the turn of the 19th century was replaced by cold weather beginning in the mid-19th century. This 1870s experienced the coldest weather during this colder trend that lasted throughout the second half of the 19th century. The December weather, while fluctuating to a great extent, became overall milder again during the 20th century. Remarkable positive anomalies were recorded in the 1910s, 1950s and 1960s, while there was a significant cooling trend between the 1920s and 1940s and in the 1960s.

Figure 34 *December temperature and precipitation 10-year averages over the decades from the 16th century until today. The first diagram (1500-1850) is based on the time series of a history based climate reconstruction, while the second diagram is based on the time series for instrument observations from the Budapest observatory (1780-1996)*



4.12.2. December Precipitation Anomalies and Medium Term Trends

The available sources of climate history information make it possible to trace changes in early winter precipitation beginning in the second half of the 16th century and it is evident that the December months remained wet until the mid-19th century, except for a drier decade mid-17th century.

Gáspár Hain wrote in his chronicle that December of **1652** was so dry in the Highlands that the water mills stopped working (*Réthly*, 1962:181; *Hain G.*, 1910-13:255). *György Czegei Vass* recorded in December of **1684** that Transylvania received an unusual amount of rain (*Réthly*, 1962:386).

December of **1728** brought considerable amounts of snow to the Highlands, according to *János Ádám Reimann*'s observations (*Réthly*, 1970:131; Nachrichten, 1729:307). He also noted that it snowed continuously in the Highlands in December of **1730** (*Réthly*, 1970:137; Nachrichten, 1730:1497). The weather was dry and cold in Transylvania in December **1762** (*Réthly*, 1970:201-202; *Halmágyi*, 1906:41), while two years later, in **1764** it rained constantly in Transylvania and in the Plain, according to reports in two different newspapers (*Réthly*, 1970:212; *Péterffy*, 1908:207). Father *István Körtvélyesi Jr.*, a Calvinist pastor wrote that the Highlands experienced rainy weather throughout December of **1773** (*Réthly*, 1970:503). *Körtvélyesi*'s diary indicates that the roads in the Highlands very muddy in December of **1775** (*Réthly*, 1970:504). *Körtvélyesi* was to report again in December of **1778** that it was extremely rainy (*Réthly*, 1970:506). The 'Pressburger Zeitung' published the news in December **1779** that due to the rainy weather there were serious spates in the Highlands unlike anything ever experienced before (*Réthly*, 1970:260; P.Z., 25th December). This series of wet early winters continued in **1780**, when the 'Magyar Hírmondó' (Hungarian Messenger) reported that the beginning of the month was rather rainy, while the second half of the month brought a lot of sleet (*Réthly*, 1970:276; M.H., 6th January, 1781). The Highlands experienced a very rainy December in **1785** to such an extent that road traffic was nearly completely disrupted according to 'Pressburger Zeitung' (*Réthly*, 1970:330; P.Z., 4th January, 1786). December of **1788** was cold and very snowy in the Highlands, and snowstorms made travel very difficult (*Réthly*, 1970:356; P.Z., 10th January, 1789) and the 'Magyar Kurír' (Hungarian Courier) reported in **1790** that even unloaded carts got stuck in the mud in the Plain due to the rainy weather (*Réthly*, 1970:274; M.K., 7th January, 1791).

December of **1841** was mild but rainy in the Plain, wrote *Gábor Ecsedy*, a Calvinist pastor (*Réthly*, 1998m:1149).

The Budapest instrument based precipitation time series indicates that December average precipitation rates varied considerably and that there is no identifiable and clear trend. The Budapest data indicates that the decades of the 1840s, 1850s, 1890s, 1920s, 1940s, 1970s and 1980s were especially dry, while the periods from the 1860s until the 1880s and from the 1900s until the 1910s, and the years of the 1950s and 1960s were very wet.

4.12.3. December Climate Change Trends over the Centuries

Temperature

The graph resulting from the 50-year average values based on climate information of a historical nature reflects a very balanced picture from the second half of the 16th until the middle of the 19th century. With only slight variations, these values approximate quite well the '0' value marking the reference average temperature. The first half of the 17th century appears to have been slightly colder, while the second half slightly milder than our reference average. The December months of the 18th century were equally cold, while they turned slightly warmer in the first half of the 19th century. The 50 year averages of the Budapest temperature time series show that there was a significant cooling trend in the second half of the 19th century, while a clear warming trend started at the turn of the 20th century which continues until today.

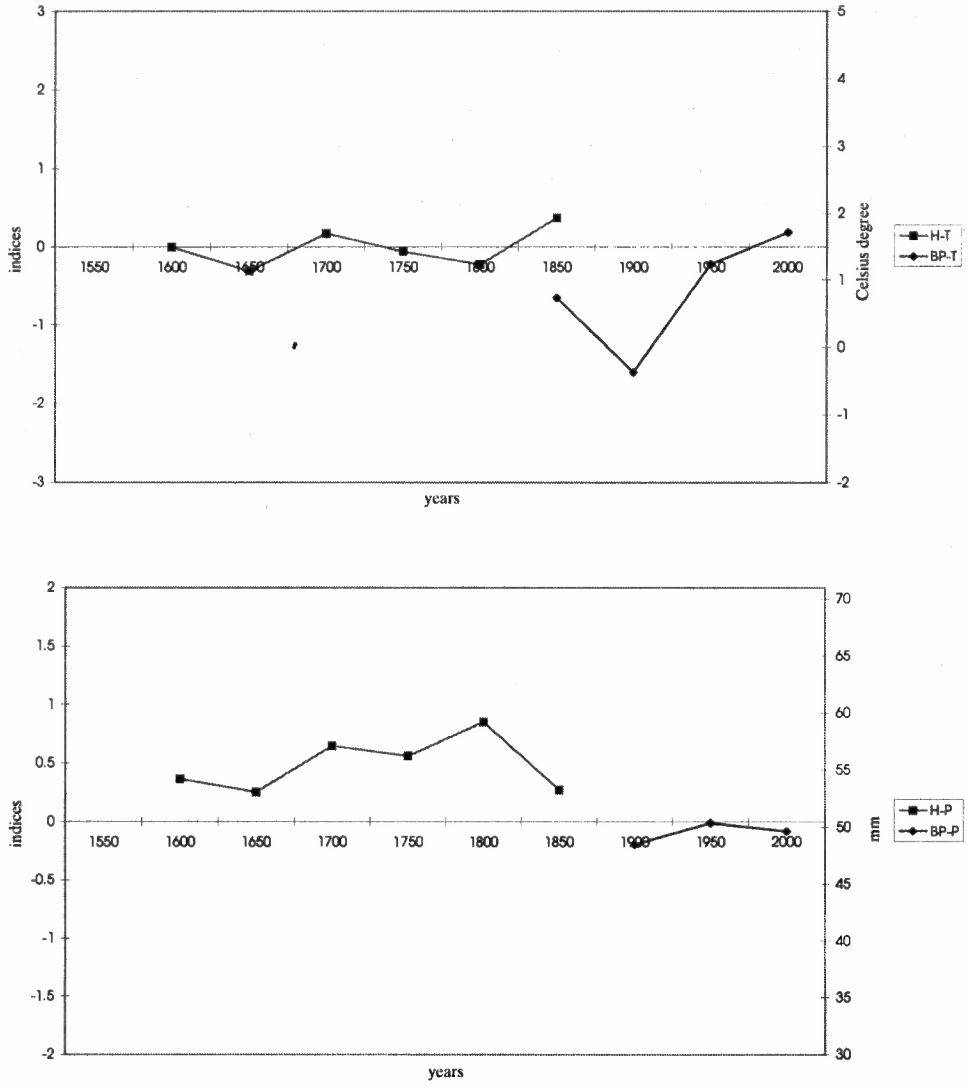
Precipitation

The 'historical' 50-year averages of the precipitation indexes show a steady precipitation surplus from the second half of the 16th until the middle of the 19th century, with the diagram of the long-term trends reaching its highest value in the second half of the 18th century. The 50-year averages of the Budapest precipitation time series do not show any significant changes in the one hundred and fifty-year period from the middle of the 19th century until the present day.

Climate Change Characteristics

A review of the 50-year averages indicates that the December months were mostly wet with average temperatures from the second half of the 16th until mid-19th century. The data of the Budapest 'instrument' based time series shows that the cold and wet late winters in the second half of the 19th century turned milder and slightly wetter in the first half of the 20th century. The further rise in the average temperature during the second half of the 20th century has been accompanied with a slight drying trend.

Figure 35 *December temperature and precipitation 50-year averages over the decades from the 16th century until today. The first diagram (1500-1850) is based on the time series of a history based climate reconstruction, while the second diagram is based on the time series for instrument observations from the Budapest observatory (1780-1996)*



Rácz, Lajos: Climate History of Hungary Since 16th Century: Past Present and Future.
Pécs: Centre for Regional Studies, 1999. 160 p.
Discussion Papers, No. 28.

5. SEASONAL CLIMATE TRENDS OF THE DECADES AND CENTURIES

The time series for the centuries were created by summarising the monthly documentary sources. As already indicated in the methodological chapter, weather summaries from the documentary sources for periods longer than a month were disregarded.

5.1. Winter

Temperature

Records of winter weather observations are available in greater and greater numbers after the second half of the 16th century than for dates prior to that. These records indicate that winter weather towards the end of the 16th century and at the turn of the 17th century was rather varied. Cold winters in the 1570s and 1600s flanked the milder winters of the 1580s.

The winters in the first two-thirds of the 17th century were very cold, part of a cooling trend that started at the beginning of the century, reaching its coldest in the 1620s, and cold winters continued to dominate until the end of the 1660s.

The winter season in the last third of the 17th and first third of the 18th century turned somewhat milder, a warming trend that ended with the mild winters in the 1720s and 1730s. Another cooling trend started towards the middle of the 18th century, producing the coldest winters in the 1740s and 1780s.

The time series for the historical reconstruction data show that Hungary had milder and milder winters in the first half of the 19th century. The Budapest winter temperature time series indicates that winters were very cold from the years of the 1830s till the end of the 19th century.

A significant warming trend began with the 20th century, reaching its first peak in the 1910s. Then, following a temporary cooling period, this trend of milder winters continued throughout the twentieth century to the present day.

Precipitation

The winter precipitation time series based on climate history reconstruction data shows a steady surplus of precipitation, with slight variations, from the second half of the 16h century practically until the end of the 18th century.

Winter precipitation rates decreased slightly in the first half of the 19th century according to the historical based reconstruction data. According to the Budapest instrument observation based winter precipitation time series, the winters in the 1850s

were the driest ones, while the snowy winters of the 1870s were followed by another dry period at the turn of the 20th century.

From the beginning of the 20th century, a trend of higher winter precipitation rates prevailed. This process reached its peak in the 1950s, the decade with the highest precipitation rates during the period for which there exists instrument based observation records for Budapest. Precipitation rates began decreasing in subsequent decades, a trend that continues to the present day.

Climate Change Characteristics

Hungary had mostly cold and snowy winters from the second half of the 16th century until the end of the 18th century. This stable situation changed at the beginning of the 19th century, when winters turned much milder and slightly drier. There was another cooling trend in the second half of the 19th century, but this was not accompanied by higher winter precipitation rates. The winter weather grew increasingly milder from the turn of the 20th century, accompanied by a rise in winter precipitation through the 1950s followed by decreased winter precipitation to the present day.

Figure 36 *Winter temperature and precipitation 10-year averages over the decades from the 16th century until today. The first diagram (1500-1850) is based on the time series of a history based climate reconstruction, while the second diagram is based on the time series for instrument observations from the Budapest observatory (1780-1996)*

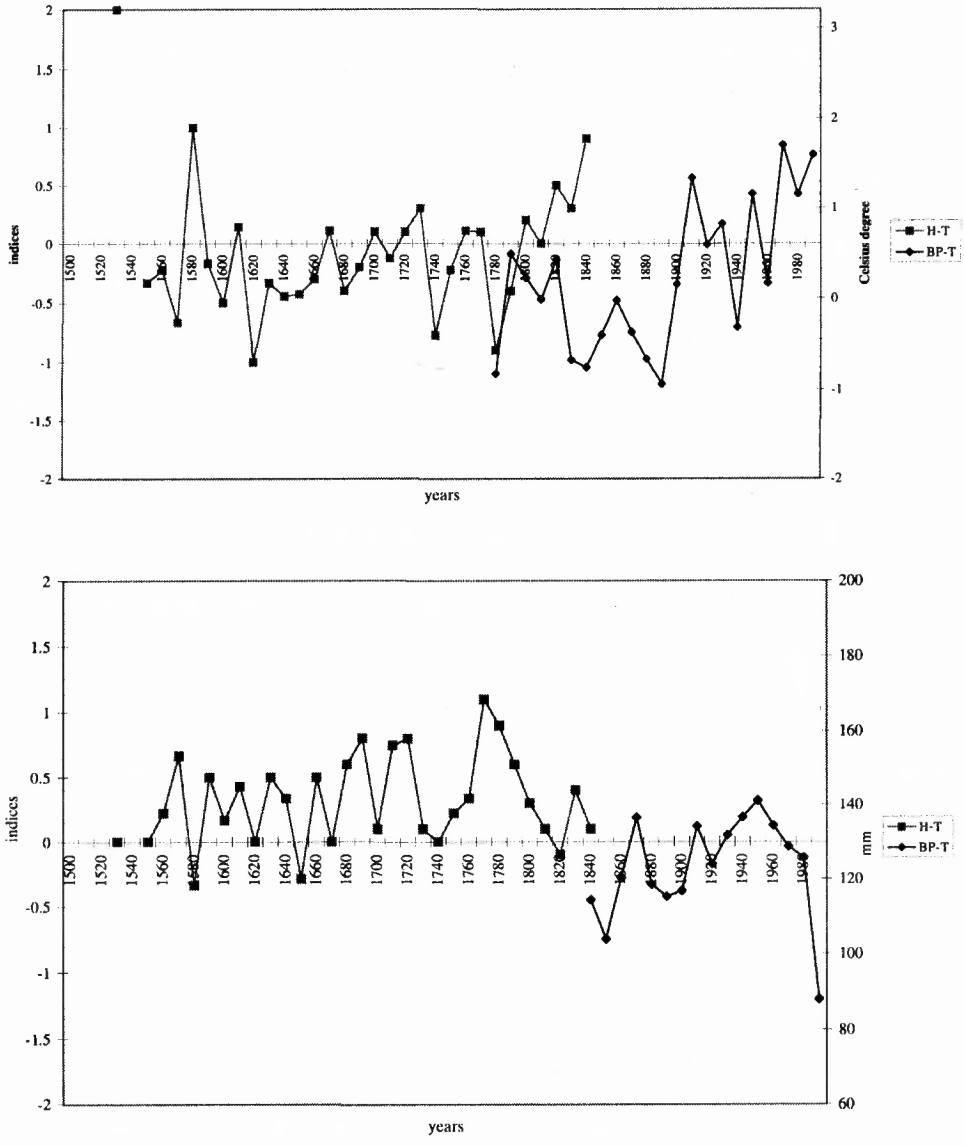
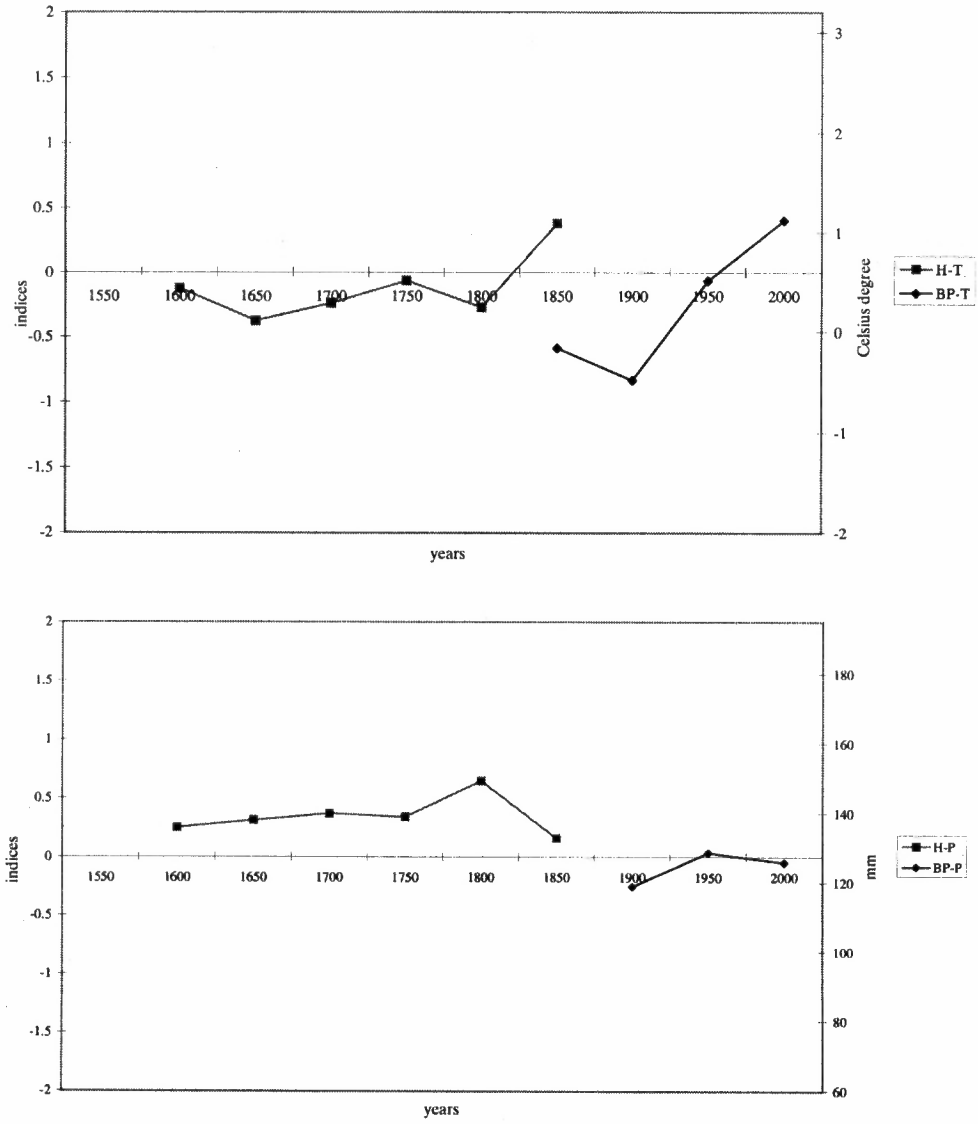


Figure 37 *Winter temperature and precipitation 50-year averages over the decades from the 16th century until today. The first diagram (1500-1850) is based on the time series of a history based climate reconstruction, while the second diagram is based on the time series for instrument observations from the Budapest observatory (1780-1996)*



5.2. Spring

Temperature

The average spring temperatures across the decades of the 16th century show large variations, and the likeliest explanation for these is that the information available from this century consists almost entirely of temperature anomalies. An analysis of the 50-averages makes it clear that the average spring temperature, for the duration of the climate history reconstruction from the beginning of the 16th century until the middle of the 19th century, remains within the cold temperature domain.

The Budapest spring temperature time series shows that the milder springs in the first two-thirds of the 19th century were followed by cooler springs in the last third of the 18th century. This trend of cooler springs carried on into the first decades of the 20th century, after which the trend turned to warmer springs beginning about a third of the way through the 20th century up to the present day.

Precipitation

The first well-documented climate change of the spring precipitation time series in the climate historical reconstruction was the dry period in the second third of the 16th century. Springs were mostly wet (i.e. exhibiting positive precipitation rates) from the second half of the 16th century till the end of the 18th century. The wettest period during this stable trend of wet springs occurred in the second half of the 17th century and the first half of the 18th century. Within this century it is possible to differentiate between three distinct cycles in the ongoing increase in precipitation rates. The first cycle peaks in the 1670s, the second in the 1700s and the third in the 1730s.

The trend toward drier springs is easily discerned in the first half of the 19th century, and the Budapest precipitation time series shows that the driest period was comprised of the very dry springs in the 1840s. Compared to previous decades, springs became much wetter at the turn of the 20th century, and the springs of the 1880s, 1910s and 1930s were particularly wet. This trend of wet springs lasted for more than half a century and ended in the mid-20th century, at which point spring weather became much drier.

Climate Change Characteristics

The data of the climate historical reconstruction shows that the Little Ice Age, which can be characterised as having brought cold and wet spring weather, determined the spring climate from the turn of the 17th to the end of the 18th century.

The spring temperatures did not vary much in the first half of the 19>th century nor through the middle of the century, but precipitation rates did decrease considerably. A drop in precipitation rates also accompanied the cooling trend in the last third of the 19th century. While the temperature time series shows a constant warming trend from the beginning of the 20>th century, it was only in the second half of the 20th century that the trend of wet springs was replaced by a drier period.

Figure 38 *Spring temperature and precipitation 10-year averages over the decades from the 16th century until today. The first diagram (1500-1850) is based on the time series of a history based climate reconstruction, while the second diagram is based on the time series for instrument observations from the Budapest observatory (1780-1996)*

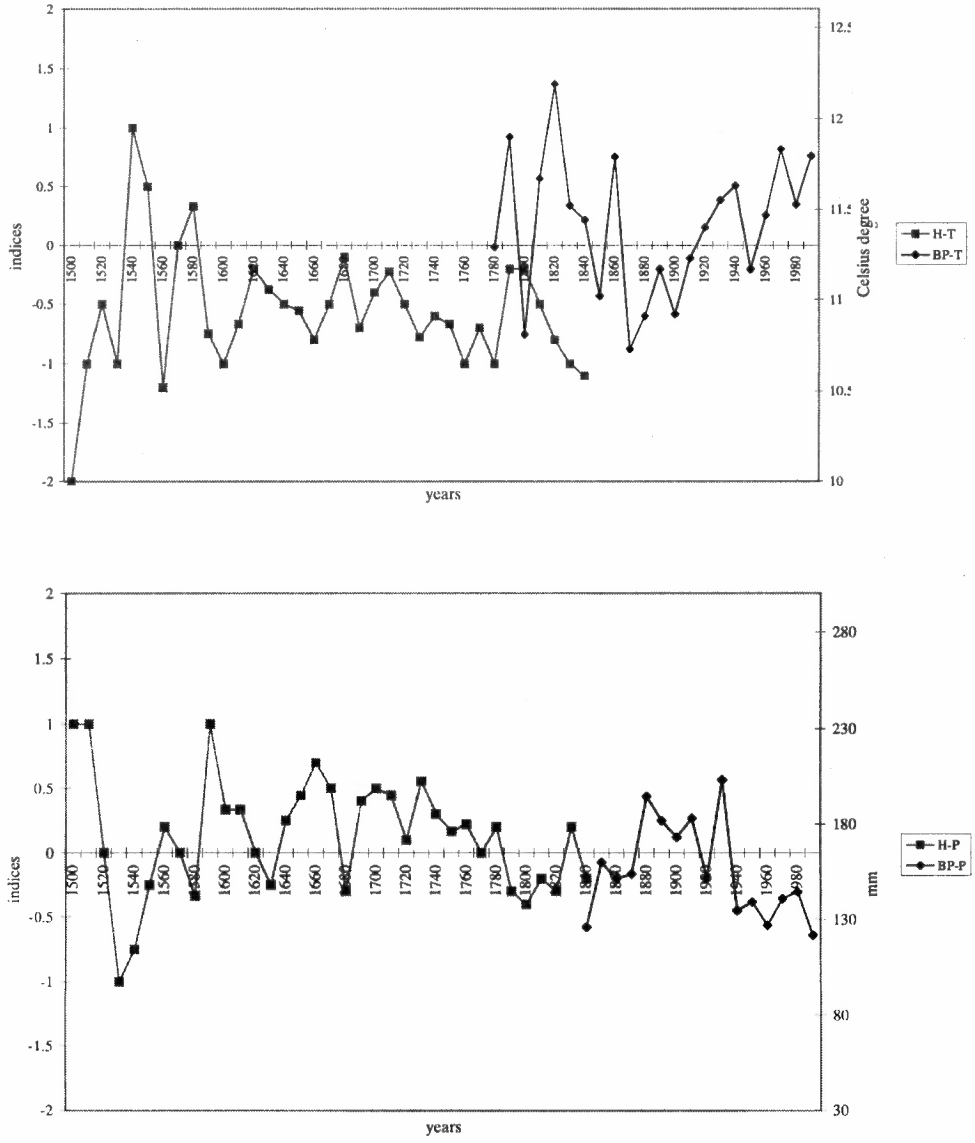
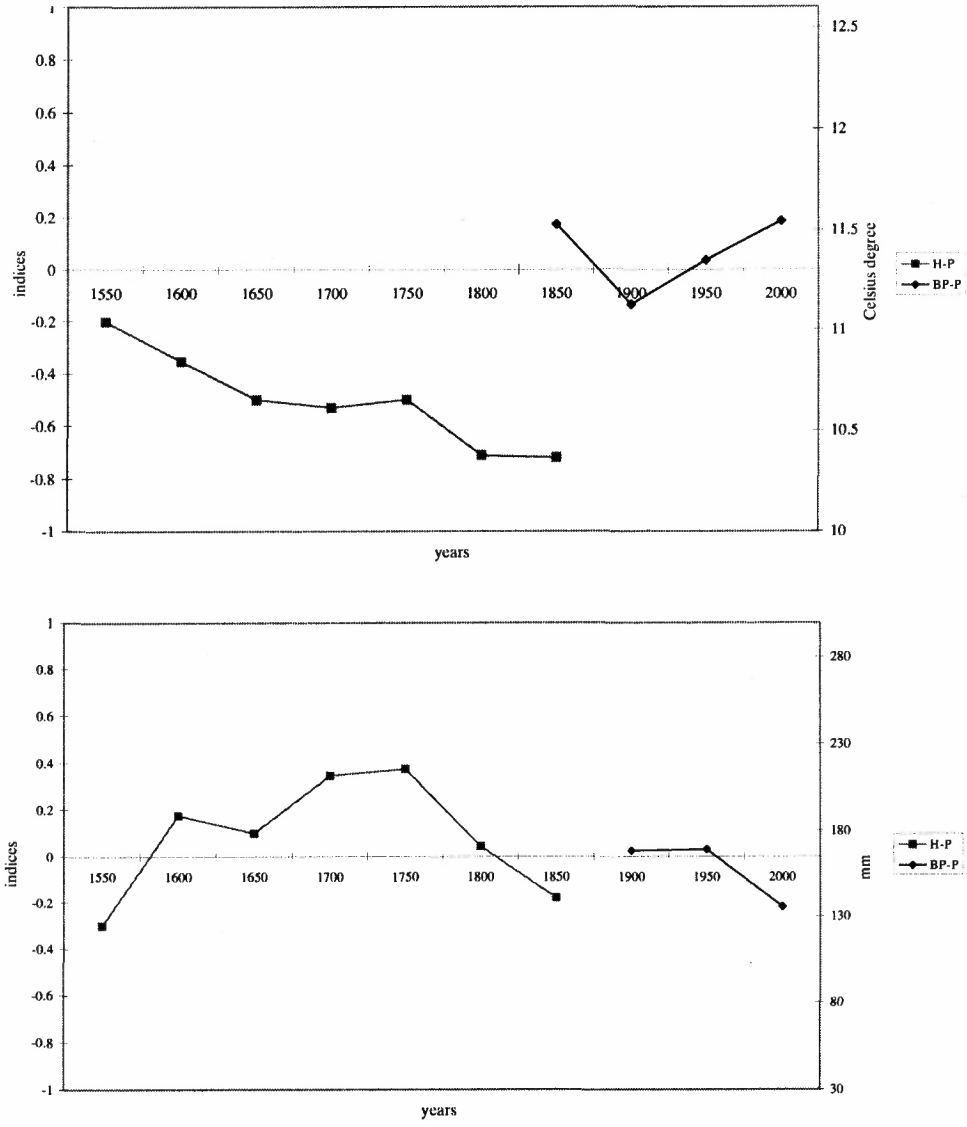


Figure 39 *Spring temperature and precipitation 50-year averages over the decades from the 16th century until today. The first diagram (1500-1850) is based on the time series of a history based climate reconstruction, while the second diagram is based on the time series for instrument observations from the Budapest observatory (1780-1996)*



5.3. Summer

Temperature

The temperature time series based on the climate history reconstruction show that the summers were invariably warm from the beginning of the 16th century until the middle of the 19th century, with the exception of only four decades from this three hundred and fifty-year period. These decades when cooler summer weather prevailed are well documented and are the following: the 1600s, 1640s, 1730s and 1760s.

The last third of the 18th century into the turn of the 19th century brought a series of unusually warm summers, nevertheless the summer weather became milder in the first half of the 19th century, and a significant cooling trend started in the mid-1800s, which lasted until the 1920s. The summer weather turned warmer again from the middle of the 20th century and while this warming trend has been somewhat balanced by the cooler summers of the period from 1960 through the 1980s, the warming trend has continued into the 1990s.

Precipitation

Summers from the 16th until the mid-18th century remained wet overall, with drier summer weather occurring only in the decades of the 1540s, 1580s, 1610s and 1680s. The unusually rainy summer period from the 1640s until the 1670s deserves special mention within this time series of predominantly wet summers.

The trend of summers becoming drier made its appearance in the last third of the 18th century, and continued until the 1860s. Summers became again wet in the last third of the 19th century and a drier period commenced again at the turn of the 20th century. Wet summer weather prevailed again from the 1910s through the 1970s, and this trend ended when dry summers made a comeback in the 1980s and 1990s.

Climate Change Characteristics

While summer weather from the beginning of the 16th century until the mid-18th century was characteristically fairly warm and wet, the second half of the 18th century brought summer weather that was significantly drier accompanied by a slightly cooling trend. (This cooling was not extensive enough however to classify the temperatures as cool compared to our reference average). The Budapest temperature time series show that the comparative decrease in both temperature and precipitation continued in the summers of the second half of the 19th century and also into the first half of the 20th century. These trends reversed in the second half of our century and through the 1970s a summer warming trend has been accompanied by a significant rise in precipitation rates. The summers of the last two decades, however, while continuing the warming trend, have been drier.

Figure 40 *Summer temperature and precipitation 10-year averages over the decades from the 16th century until today. The first diagram (1500-1850) is based on the time series of a history based climate reconstruction, while the second diagram is based on the time series for instrument observations from the Budapest observatory (1780-1996)*

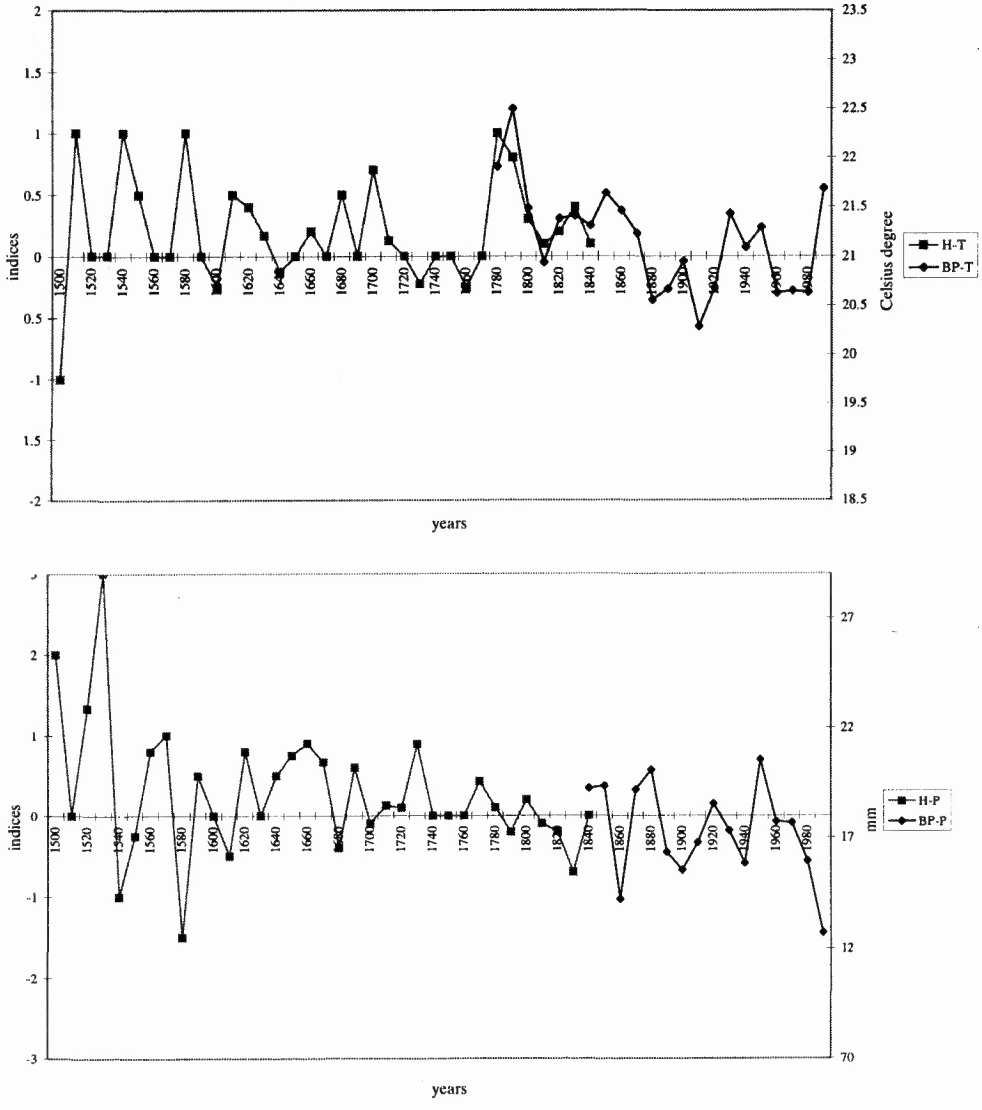
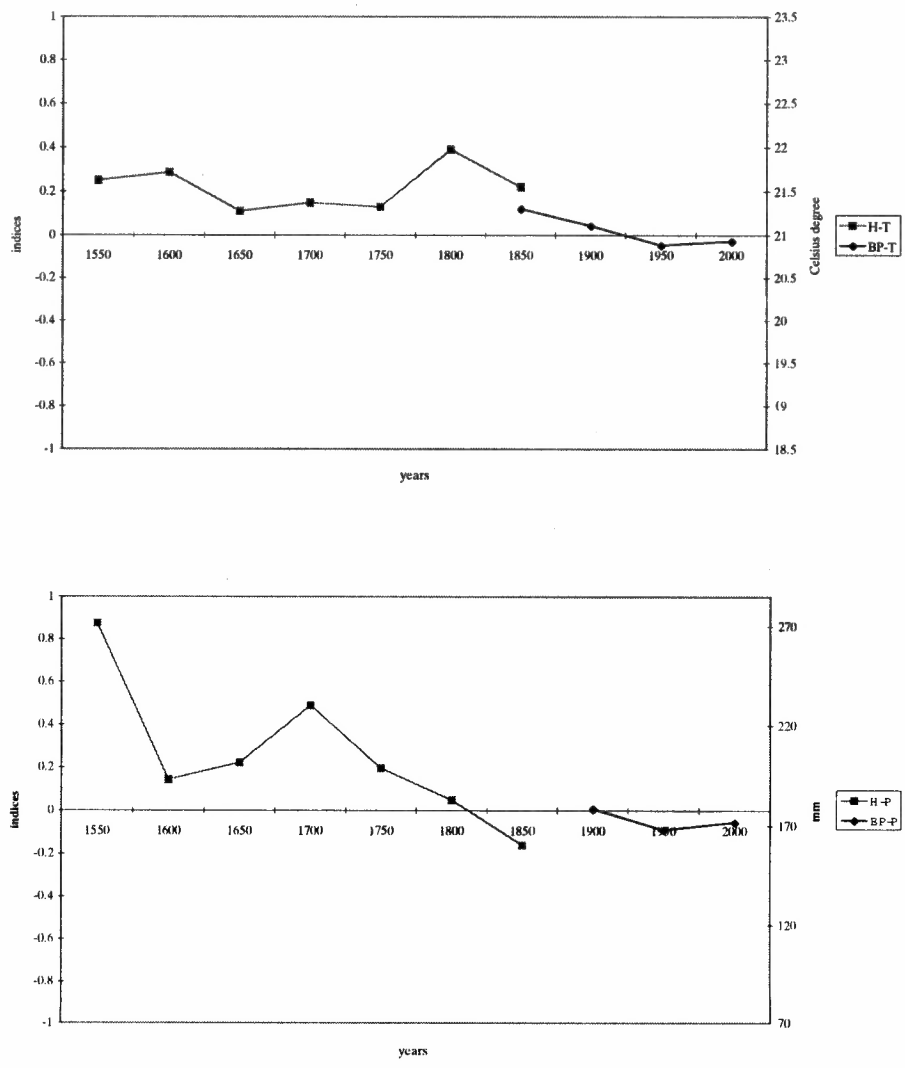


Figure 41 *Summer temperature and precipitation 50-year averages over the decades from the 16th century until today. The first diagram (1500-1850) is based on the time series of a history based climate reconstruction, while the second diagram is based on the time series for instrument observations from the Budapest observatory (1780-1996)*



5.4. Autumn

Temperature

A review of the averages calculated for ten-year and fifty-year periods as per the temperature time series based on the reconstructed climate history will illustrate that autumn weather was mostly cool and cold from the beginning of the 16th until the end of the 18th century. The cold character of the autumn weather was more notable until the mid-17th century, while the following decades experienced particularly cold autumns; the 1590s, 1600s and 1630s. Autumns of the one hundred and fifty year period from the mid-16th until the late 18th century were just moderately cool, with the exception of the notably cold autumns between the 1710s and 1740s.

According to the historical indexes, the autumn weather turned milder in the first half of the 19th century. The Budapest temperature time series concurs quite reasonably, showing that this mild-trend came at the turn of the 19th century. The equally mild and sometimes very mild autumns in the first half of the 19th century were replaced in the second half of the century and at the turn of the 20th century by autumn weather that was mostly cold in nature. The autumn weather turned much milder after the 1920s, a warming trend that reached its peak in the 1940s and 1960s respectively, followed by a slight cooling trend.

Precipitation

The precipitation time series based on reconstructed climate history show that autumn weather remained constantly wet from the beginning of the 16th until the end of the 18th century. There was only one decade, the 1580s, that is classified as dry. The most notably rainy of this long period of wet decades were as follows: the 1540s, 1590s, 1670s, 1750s and 1790s.

Autumn weather became drier in the first half of the 19th century, a trend that continued until the 1860s, as shown by the Budapest precipitation time series. In the last third of the 19th century autumns turned wet again, and this predominance of wet autumns prevailed until the 1930s. Autumn weather again turned drier mid-20th century and this trend which strengthened in the 1970s, continues till today.

Climate Change Characteristics

The autumns from the early 16th until the late 18th century were mostly cool and wet. The autumn weather turned milder and drier in the first half of the 19th century according to the time series of the climate history reconstruction.

The Budapest meteorological instrument time series show that autumns in the second half of the 19th century were rather cool and dry. They became much warmer after the turn of the 20th century, followed by a rise in the precipitation rate until the middle of the 20th century. The autumn weather in the second half of our century while warm, has become much drier as we approach the millennium.

Figure 42 *Autumn temperature and precipitation 10-year averages over the decades from the 16th century until today. The first diagram (1500-1850) is based on the time series of a history based climate reconstruction, while the second diagram is based on the time series for instrument observations from the Budapest observatory (1780-1996)*

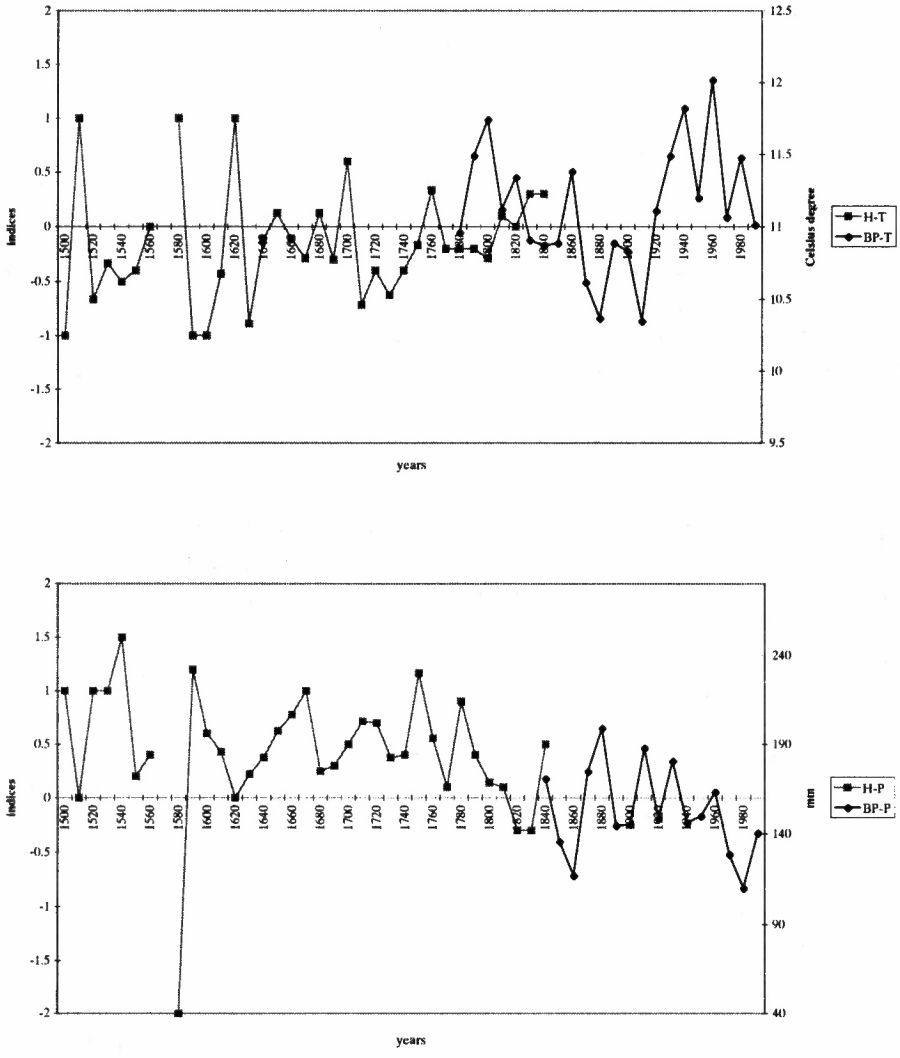
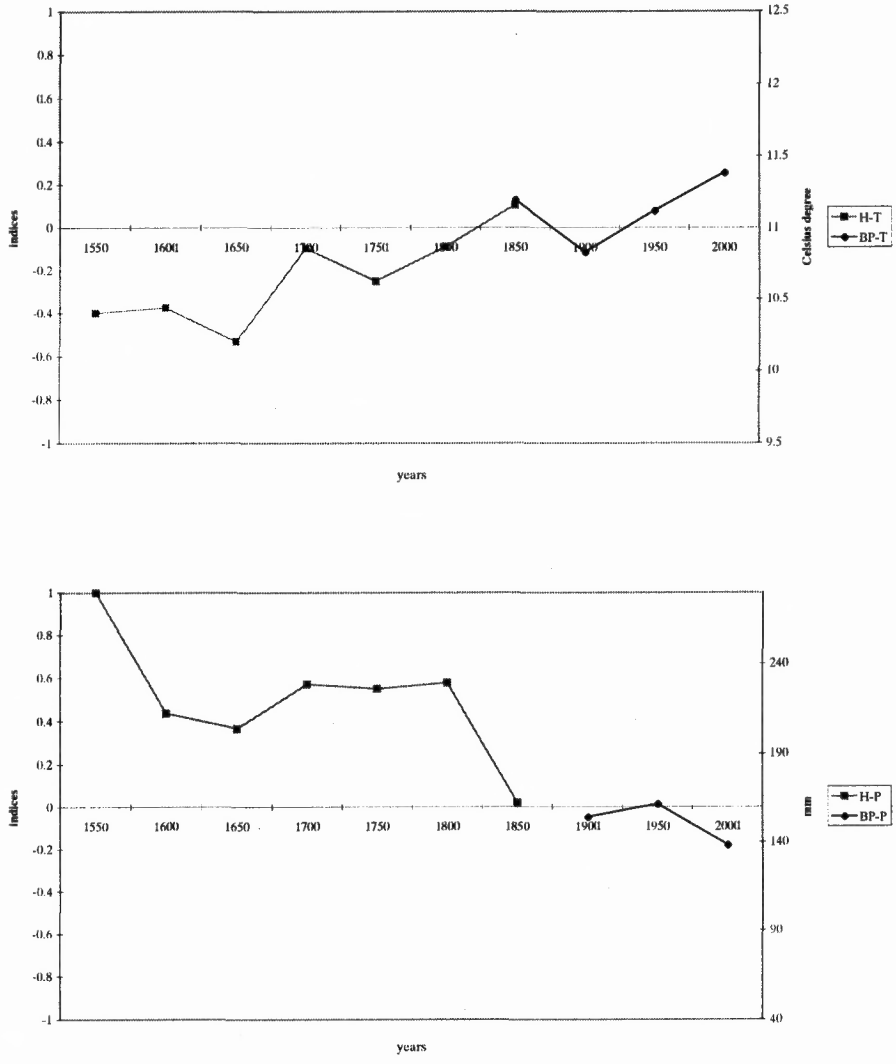


Figure 43 *Autumn temperature and precipitation 50-year averages over the decades from the 16th century until today. The first diagram (1500-1850) is based on the time series of a history based climate reconstruction, while the second diagram is based on the time series for instrument observations from the Budapest observatory (1780-1996)*



Rácz, Lajos: Climate History of Hungary Since 16th Century: Past Present and Future.
Pécs: Centre for Regional Studies, 1999. 160 p.
Discussion Papers, No. 28.

6. HALF-YEARLY AND YEARLY CLIMATE CHANGE TRENDS

This chapter deals with temperature and precipitation time series for the six-month winter and summer periods based on monthly data, as well as with an analysis of the temperature and precipitation time series from the point of view of a twelve-month period.

6.1. Winter Half-Year

I used the averages of the months from October through March to analyse the climate change trends during the 'winter' half-year period.

Temperature

The weather during the winter half-year was cool overall, and in certain periods even very cold from the beginning of the 16th, until the end of the 18th century. This predominance of cool weather was significantly interrupted only in the second half of the 16th century by a milder period, which was followed by an extremely cold one in the first half of the 17th century. The other outstanding feature of the winter half-year temperature time series is the trend towards milder weather beginning in the mid-17th century and continuing into the middle of the 19th century. The climate history based indexes of the first half of the 19th century show that the winter half-year weather of this period was sometimes very mild.

The Budapest temperature time series shows that the winter half-year weather turned cold from the 1840s until the end of the 19th century. Another significant warming trend appeared early in the 20th century, which has since remained stable except for a short period in the 1940s.

Precipitation

The precipitation time series based on climate history reconstruction shows that the winter half-years remained wet from the early 16th century until the mid-19th century. Within this period covering three and a half centuries, the only characteristically dry winter half-years were in the 1580s. Subsequently, a drying trend became apparent in the first half of the 19th century, bottoming out in the 1860s.

The Budapest precipitation time series shows that the weather of the winter half-year periods turned wet again in the last third of the 19th century. This was followed by a drier period at the turn of the 20th century, and then another wet trend developed in the second third of the 20th century. The winter half-year periods became drier and

drier in Hungary in the last third of the 20th century after exhibiting the highest precipitation levels in the 1930s and 1950s.

Climate Change Characteristics

The weather of the winter half-years was predominantly cool and wet from the early 16th until the late 18th century. This characteristic changed slightly in the first half of the 19th century, when the winter half-years turned somewhat milder and drier.

The Budapest time series shows that winter half-year weather became cold and wet in the second half of the 19th century. This was followed by a significant warming trend in the 20th century, which was accompanied by a precipitation increase through the second third of the 20th century. While this warming trend continued into the last third of our century, precipitation levels have shown a considerable decrease in the past three decades.

Figure 44 *Winter Half-Year temperature and precipitation 10-year averages over the decades from the 16th century until today. The first diagram (1500-1850) is based on the time series of a history based climate reconstruction, while the second diagram is based on the time series for instrument observations from the Budapest observatory (1780-1996)*

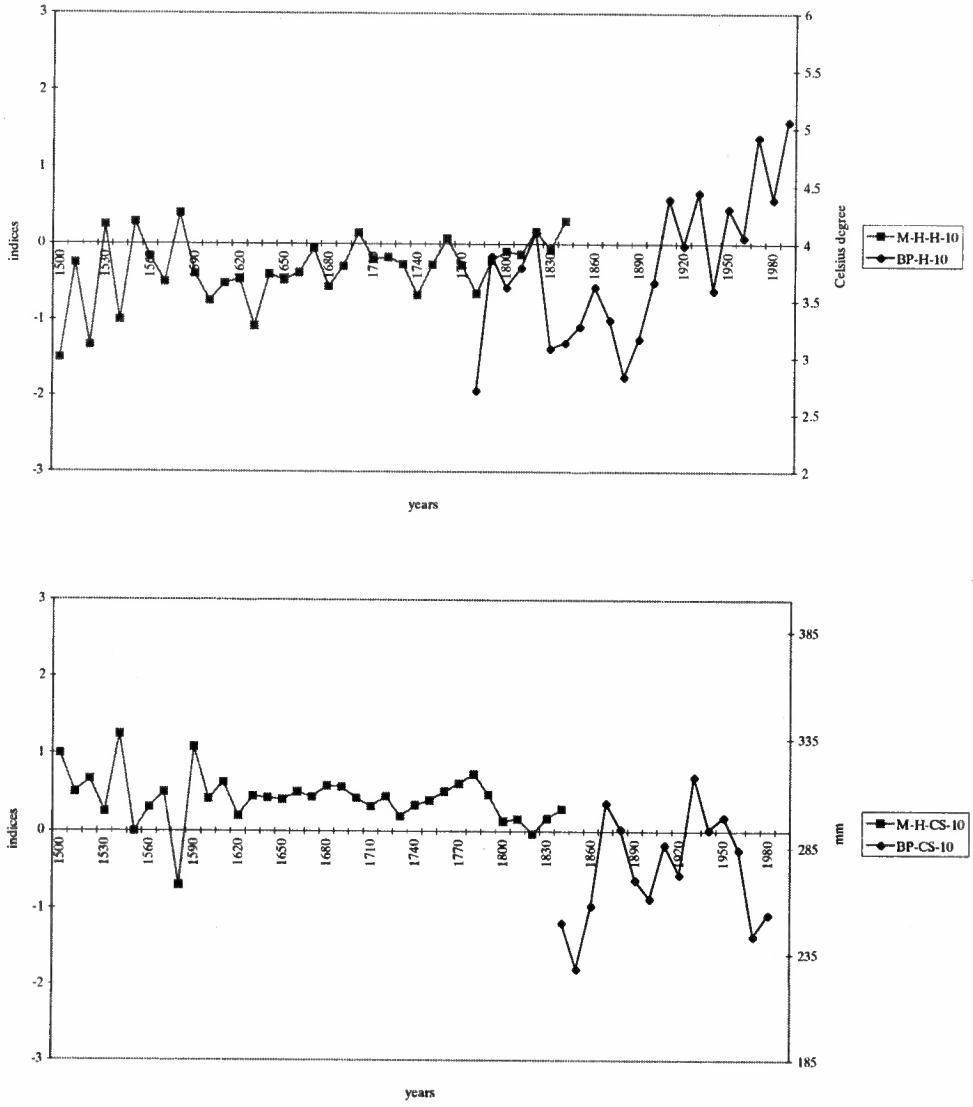
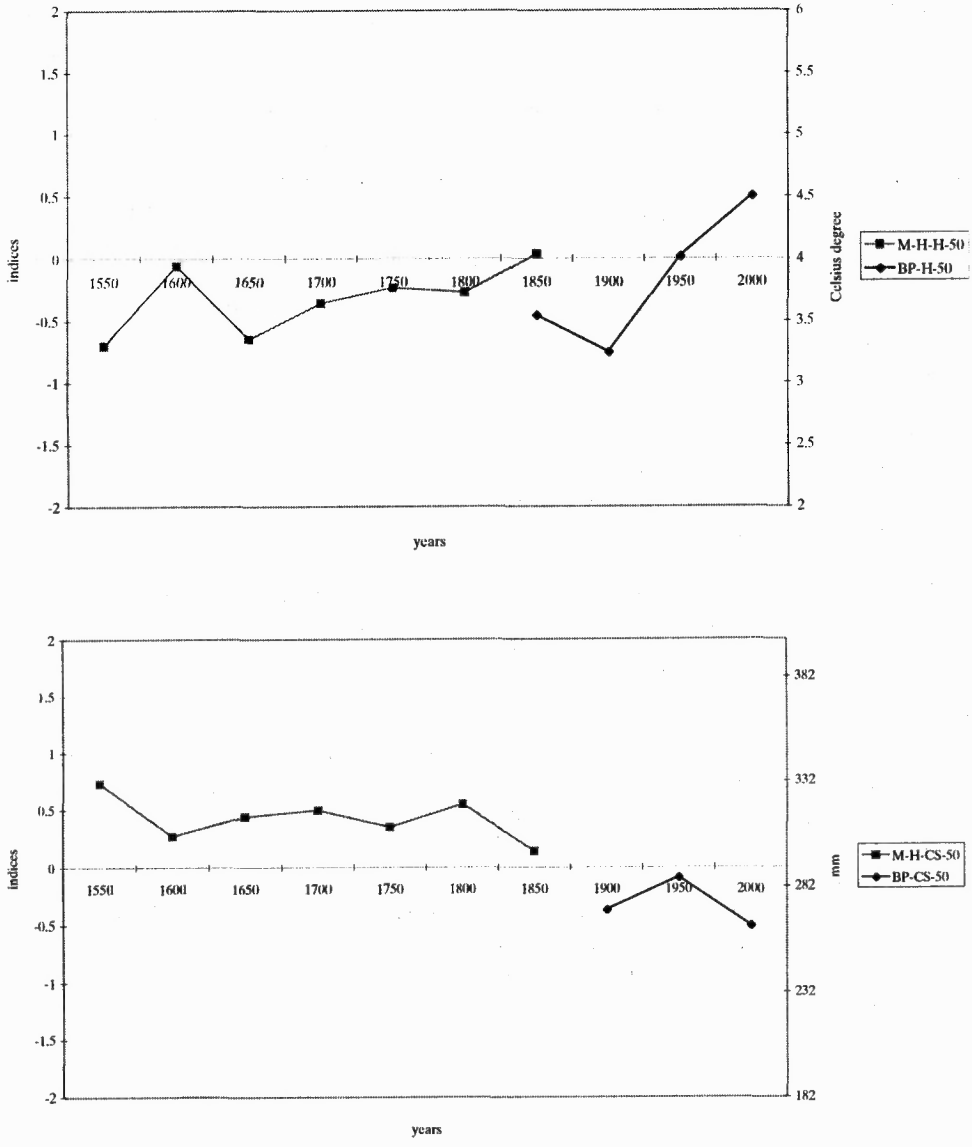


Figure 45 *Winter Half-Year temperature and precipitation 50-year averages over the decades from the 16th century until today. The first diagram (1500-1850) is based on the time series of a history based climate reconstruction, while the second diagram is based on the time series for instrument observations from the Budapest observatory (1780-1996)*



6.2. Summer Half-Year

I used the averages of the months from April through September to analyse the climate change trends during the 'summer' half-year period.

Temperature

Average summer half-year temperatures by decade for the duration of the period covered by the climate history reconstruction methods are quite constant around the '0' value marking the reference average, with the exception of some slight variations. (Once again we are forced to disregard the sparse amount of data available for the first half of the 1500s as statistical inadequate.) This considerably stable period from the 16th until the mid-19th century was followed by a significant cooling period in the second half of the 19th century which continued into the first third of the 20th century, as shown by the data of the Budapest temperature time series. The weather of the summer half-years turned somewhat warmer in the middle of the 20th century, but there was a cool period from the 1960s through the 1980s, which was more reminiscent of the weather at the turn of the century. This was followed by a renewed warm trend, which has continued over the last decades of our century.

Precipitation

The summer half-year weather remained consistently wet from the early 16th century until the late 18th century. There were some distinctly dry decades during the 16th century (1540s, 1580s) but the 17th and 18th centuries experienced a predominance of wet summer half-year weather.

There was a dry trend at the turn of the 19th century, which continued in the second half of the 19th, and continued into the 20th century, as shown by the decade and half-century averages of the Budapest precipitation time series.

Climate Change Characteristics

The summer half-year weather from the second half of the 16th century through the end of the 18th century exhibited stable temperatures and was slightly wet. The weather of the summer half-years in the first half of the 19th century turned drier and slightly warmer.

The decade and the half-century averages of the Budapest temperature time series show that the climate of the summer half-years became significantly colder and drier from the mid-19th until the mid-20th century. This dry trend continued in the second half of our century as well, but the cool trend reversed into a slight warming trend in latter decades.

Figure 46 *Summer Half-Year temperature and precipitation 10-year averages over the decades from the 16th century until today. The first diagram (1500-1850) is based on the time series of a history based climate reconstruction, while the second diagram is based on the time series for instrument observations from the Budapest observatory (1780-1996)*

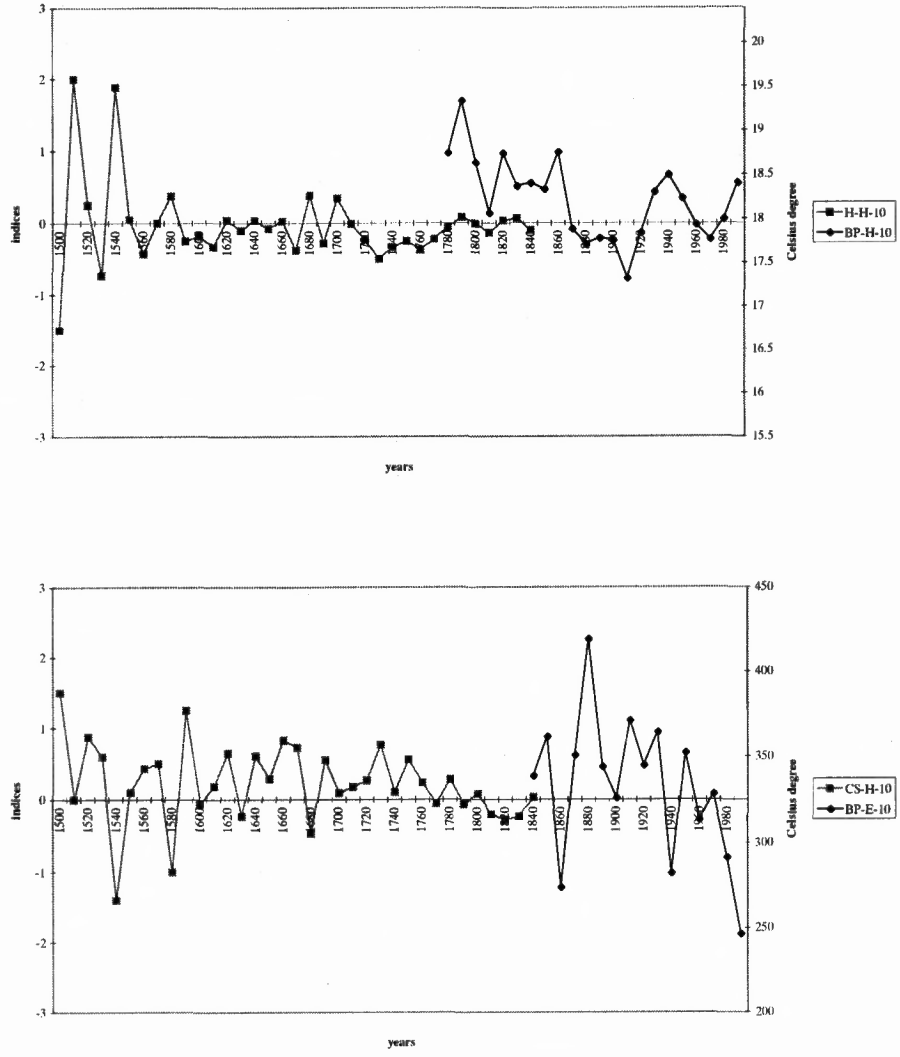
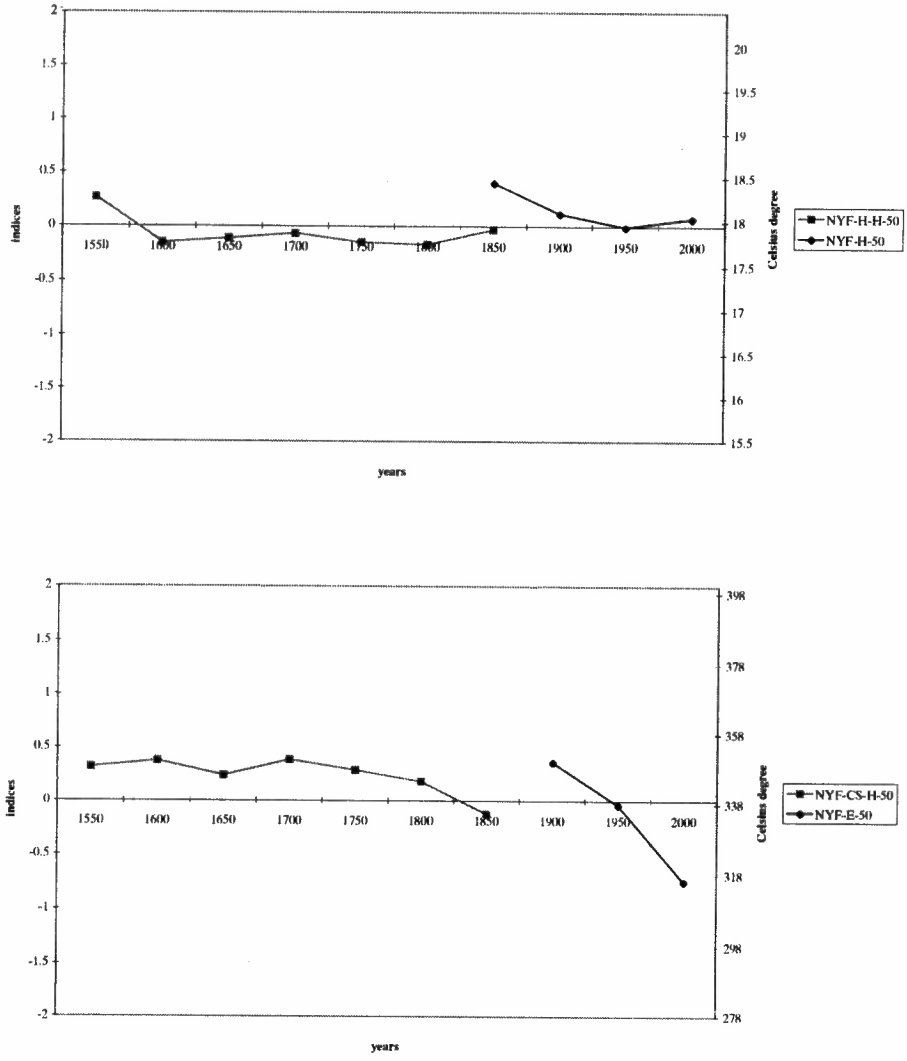


Figure 47 *Summer Half-Year temperature and precipitation 50-year averages over the decades from the 16th century until today. The first diagram (1500-1850) is based on the time series of a history based climate reconstruction, while the second diagram is based on the time series for instrument observations from the Budapest observatory (1780-1996)*



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6.3. Yearly Temperature and Precipitation Time Series

Temperature

The decade and half-century temperature averages show a predominance of cool years from the early 16th through the late 19th century. The decades of the 16th century which exhibited very unstable average temperatures (and which are quite poorly documented), the long cold period in the first half of the 17th century, the milder years at the turn of the 18th century, and the cold period of the 18th century can all be separately defined within this predominantly cool trend. Both the historical data and the Budapest temperature time series show that the years turned milder in the first half of the 19th century. But this mild trend was followed first by a slightly cool period in the mid-19th century, and later by a significant cold period in the last third of the 19th century. The warming trend that started early in the 20th century has continued, while exhibiting major fluctuations, throughout our century.

Precipitation

The time series based on climate history reconstruction shows that the years from the early 16th century through the late 18th century were constantly wet in Hungary. The transition to drier trends started at the turn of the 19th century, and continued through the 1860s, according to the data of the Budapest precipitation time series. The years in the last third of the 19th and the first half of the 20th century were mostly wet. In the 1960s a significant and stable drying trend began that continues to the present day.

Climate Change Characteristics

The years from the early 16th century through the late 18th century were moderately cool and consistently wet. The weather in the first half of the 19th century turned somewhat milder and less wet. The Budapest time series shows that the yearly precipitation rates did not change considerably during the strong cooling period during the second half of the 19th century. There was a warming trend early in the 20th century, which basically determined the climate processes of the whole century. The warming trend, which came in with the 20th century, was not accompanied by a change in precipitation decade averages until the 1930s. The yearly precipitation rate started to significantly decrease from the 1940s through the end of our century.

Figure 48 *Yearly temperature and precipitation 10-year averages over the decades from the 16th century until today. The first diagram (1500-1850) is based on the time series of a history based climate reconstruction, while the second diagram is based on the time series for instrument observations from the Budapest observatory (1780-1996)*

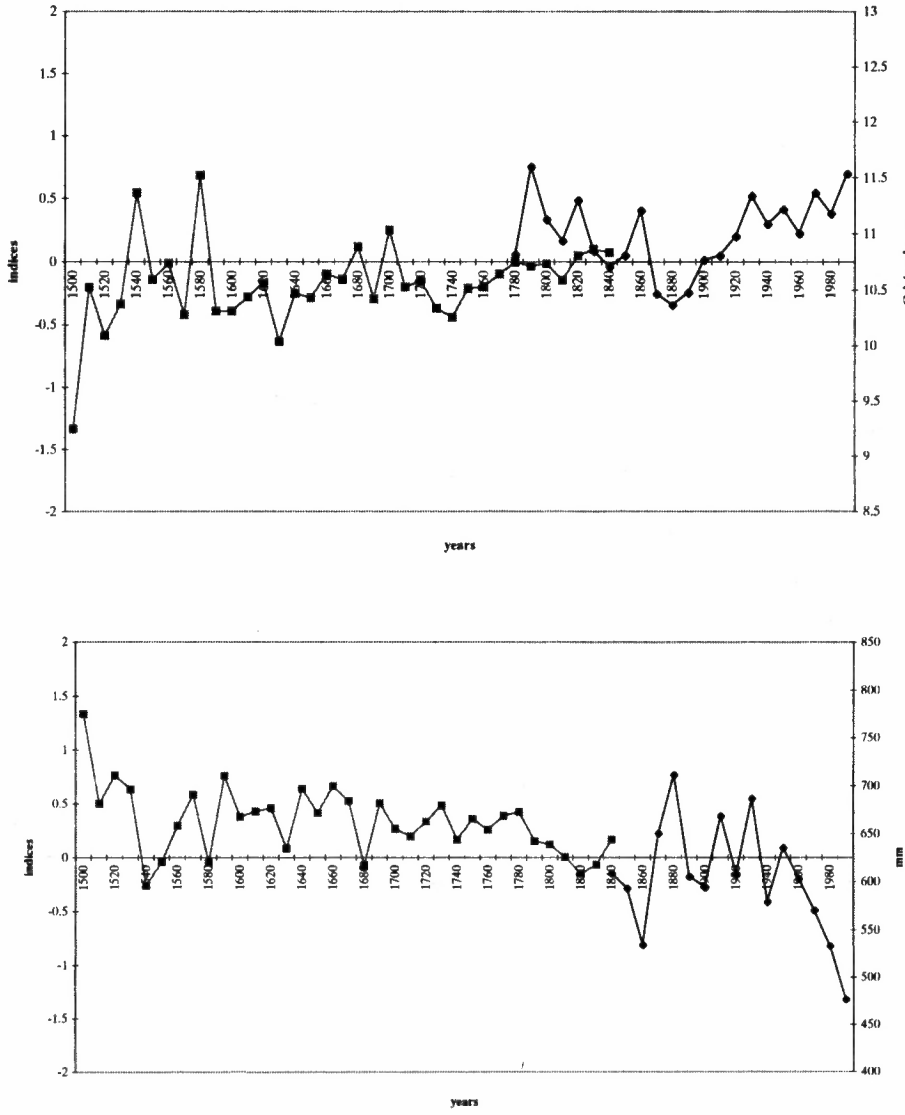
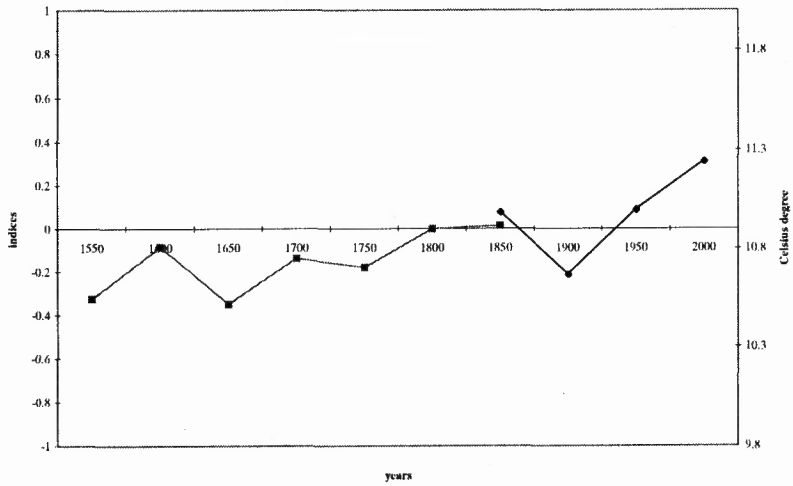
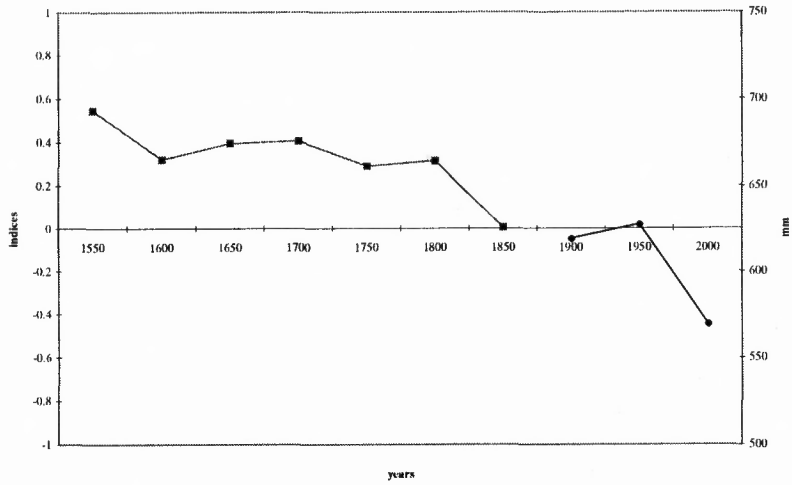


Figure 49 *Yearly temperature and precipitation 50-year averages over the decades from the 16th century until today. The first diagram (1500-1850) is based on the time series of a history based climate reconstruction, while the second diagram is based on the time series for instrument observations from the Budapest observatory (1780-1996)*





7. CLIMATE CHANGE CHARACTERISTICS IN HUNGARY DURING THE LITTLE ICE AGE AND THE RECENT WARMING

In the last chapter of my study my goal is to summarise the most significant elements of my research regarding climate history. I will attempt to explore the inner structure of the climate changes in the Carpathian Basin with the help of correlation studies. Furthermore, I will endeavour to characterise the Hungarian specific features of the climate changes in the Little Ice Age and during the recent warming, based on the results of the climate-process-analyses and from a statistical point of view. Finally I will establish a prognosis of the expected direction and characteristics of future changes in climate.

7.1. Correlation Study of the Climate History and Meteorological Monthly Time Series

From the time series based on the reconstructed climate history and the time series based on instrument measurements, I used only the results of the correlation studies of the temperature time series, as I found no relevant correlation within the precipitation time series.

I selected three periods for the correlation studies, respecting traditional methods of climate research. The first period is from 1675 and 1715, which is referred to in European climate research as a typical period of the Little Ice Age and for which there exists sufficient climate history information sources (unlike the situation for the last third of the 16th century). The second period selected is the forty year period of the recent warming trend from 1960 through the 1990s, which is also considered typical within the discipline. Finally, I used the data for the sixty-year period from 1901 through 1960 as the control period, the averages of which are considered as a base for reference and comparison in international meteorological research.

I used the monthly temperature averages for the correlation studies, as the time series of the 17th-18th century could be compared with the meteorological measurement based time series only with this as a condition.

1675-1715

The correlation studies illustrate quite well that the cooling trend in this cold period of the Little Ice Age is reflected most significantly in the average temperatures of the January and February months, but it was also clear that the March temperature followed the pattern of the two winter months. The actual transition to spring during this period occurred between March and April, which is well reflected in the difference of

the average temperatures from the two winter months. The close correlation of the April and June average temperatures is worthy of note from a climate history point of view, i.e. the June months had nothing in common with the temperature processes of the two other summer months. Correlation was, however, found between July and August, as well as between July and September, but there is no correlation between the August and September temperature time series. The correlation study of the three autumn months reflected the same trends, and a similar movement of temperature averages. It is also worthy of note that the December weather in this period of the Little Ice Age became rather more like autumn, and a positive correlation can be established to the temperature changes of the October and November months. The result was negative however when attempting to correlate December with the winter-like March months.

Based on my correlation studies it seems that the structure of the natural seasons changed in this expansive period of the Little Ice Age. The truly cold weather began early in January, but often ended as late as the end of March. Spring started with April, but in reality June also became a spring month. The summer period was reduced to July and August. The normally transitory weather of autumn, on the other hand, continued from September till December.

Table 3 *Correlation studies between the monthly temperature time series from 1675-1715. The values in darker shading show a 99 %, while those in lighter shading reflect a 95 %, significance level.*

1675-1715	Jan	Feb.	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Jan	1	0.716	0.341	-0.568	-0.264	-0.243	-0.286	-0.154	0.226	-0.086	-0.016	-0.156
Feb.	0.716	1	0.294	0.390	-0.183	-0.242	-0.061	-0.052	0.354	-0.055	0.191	-0.111
Mar.	0.341	0.294	1	-0.099	0.162	0.224	0.099	0.118	0.441	-0.023	-0.060	-0.468
Apr	-0.568	0.390	-0.099	1	0.222	0.456	0.107	0.026	0.008	0.038	0.144	-0.025
May	-0.264	-0.183	0.162	0.222	1	0.124	0.004	-0.225	0.219	-0.110	0.125	-0.025
Jun	-0.243	-0.242	0.224	0.456	0.124	1	0.270	0.056	0.257	0.098	0.268	0.090
Jul	-0.286	-0.061	0.099	0.107	0.004	0.270	1	0.391	0.312	0.189	0.038	0.061
Aug	-0.154	-0.052	0.118	0.026	-0.225	0.056	0.391	1	0.043	0.546	0.257	-0.076
Sep.	0.226	0.354	0.441	0.008	0.219	0.257	0.312	0.043	1	0.307	0.331	-0.067
Oct	-0.086	-0.055	-0.023	0.038	-0.110	0.098	0.189	0.546	0.307	1	0.469	0.307
Nov	-0.016	0.191	-0.060	0.144	0.125	0.268	0.038	0.257	0.331	0.469	1	0.546
Dec	-0.156	-0.111	-0.468	-0.025	-0.025	0.090	0.061	-0.076	-0.067	0.307	0.546	1

1901-1960

The strong correlation between January and February was remarkable in this 60-year period as well, but there is no real correlation between the March or April temperature time series. It is, however, quite interesting to observe the significant negative correlation between the January and June months. The February time series is a good indicator of the winter and spring temperature process, as it has significant positive correlation with the time series of each month between January and April.

Analysing the summer months, the relative 'isolation' of the June months and the strong common move of the 'summer season' July-August-September becomes apparent. It is quite interesting that there is a significant positive correlation between the July and June, and July and May months respectively.

There are not any very significant correlations between the autumn months, and it is worth noting that the December temperature time series shows no significant correlation with any other month.

The results of the correlation studies seem to prove that the contrasts between the seasons decreased during the sixty years analysed. Winters are not so strongly delineated from the spring, as was experienced during the Little Ice Age. The period of the summer weather became longer and lasted from May till the end of September.

Table 4 *Correlation studies between the temperature time series by month between 1901 and 1960. The values in darker shading show a 99 %, while those in lighter shading show a 95 %, significance level.*

1901-1960	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Jan	1	0.385	0.131	0.164	-0.064	-0.282	0.012	-0.026	-0.211	-0.116	-0.098	-0.145
Feb.	0.385	1	0.378	0.268	-0.005	-0.067	0.129	-0.091	-0.231	-0.160	0.064	-0.071
Mar.	0.131	0.378	1	0.177	-0.053	0.034	-0.008	-0.102	-0.070	-0.274	0.021	0.114
Apr	0.164	0.268	0.177	1	0.073	-0.044	0.243	0.163	0.231	-0.160	0.058	0.040
May	-0.064	-0.005	-0.053	0.073	1	0.109	0.257	0.094	0.123	-0.009	-0.023	0.166
Jun	-0.282	-0.067	0.034	-0.044	0.109	1	0.[illegible]	0.097	0.013	-0.129	0.049	0.017
Jul	0.012	0.129	-0.008	0.243	0.[illegible]	0.[illegible]	1	0.491	0.150	-0.238	0.140	-0.108
Aug	-0.026	-0.091	-0.102	0.163	0.094	0.097	0.491	1	0.448	0.154	0.198	-0.014
Sep.	-0.211	-0.231	-0.070	0.231	0.123	0.013	0.150	0.448	1	0.[illegible]	0.[illegible]	0.013
Oct	-0.116	-0.160	-0.274	-0.160	-0.009	-0.129	-0.238	0.154	0.[illegible]	1	0.198	0.018
Nov	-0.098	0.064	0.021	0.058	-0.023	0.049	0.140	0.198	0.[illegible]	0.198	1	0.048
Dec	-0.145	-0.071	0.114	0.040	0.166	0.017	-0.108	-0.014	0.013	0.018	0.048	1

1961-1990

In the four decades of the present warming trend, the correlation between the January and February temperature time series decreased, but the time series of both winter months are strongly correlated to the March temperature time series.

The other apparent interesting feature of the correlation study is that the summer months 'diverged'. The June temperature time series correlate neither with the spring, nor with the summer months, while the July temperature time series apparently correlate with no other month at all. Interestingly enough the August time series showed a significantly positive correlation with the May time series, and a similarly significant, but negative correlation, with the June temperature time series.

With regard to the autumn weather it is interesting to note the strong 'opposite movement' of the November and December temperature time series.

The most important climate characteristic of the forty years analysed during the recent warming trend is that the winter months have become remarkably 'spring-like'. Moreover it cannot be ignored that the climatic character of summers has weakened as well.

Table 5 Correlation studies between the temperature time series of the months between 1961-1990. The values in darker shading show a 99 %, while those in lighter shading show a 95 %, significance level.

1961-1990	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Jan	1	0.262		0.042	0.235	-0.296	0.024	0.250	-0.137	-0.145		0.113
Feb	0.262	1		0.0004	0.068	0.049	-0.166	0.070	-0.282	0.113	-0.081	0.231
Mar			1	-0.105	0.170	0.074	-0.229	0.136	0.010	-0.024	-0.189	0.219
Apr	0.042	0.0004	-0.105	1	0.096	0.077	0.258	0.152	-0.015	0.201	0.226	-0.271
May	0.235	0.068	0.170	0.096	1	0.035	0.272		0.086	0.019	-0.052	0.104
Jun	-0.296	0.049	0.074	0.077	0.035	1	0.090		0.077	-0.021		-0.169
Jul	0.024	-0.166	-0.229	0.258	0.272	0.090	1	0.014	0.162	-0.051	0.046	-0.048
Aug	0.250	0.070	0.136	0.152			0.014	1	0.140	-0.210	-0.068	0.043
Sep	-0.137	-0.282	0.010	-0.015	0.086	0.077	0.162	0.140	1	0.265	-0.029	0.090
Oct	-0.145	0.113	-0.024	0.201	0.019	-0.021	-0.051	-0.210	0.265	1	0.037	-0.240
Nov		-0.081	-0.189	0.226	-0.052		0.046	-0.068	-0.029	0.037	1	
Dec	0.113	0.231	0.219	-0.271	0.104	-0.169	-0.048	0.043	0.090	-0.240		1

7.2. Hungarian Features of the Climate Changes

In respect of the results of my climate history analysis, I believe I have identified four basically new conclusions:

a.

One of the most important signs of the climatic changes in the Carpathian Basin is the change in the duration and defining time limits of the 'natural seasons'. March practically turned into a winter month during the Little Ice Age, while June was more like a spring month and the summer period was limited to July and August. Due to the recent warming trend, the weather of the winter months became more spring-like, while the summer months separate climate character was detracted from.

b.

Analysing the temperature and precipitation time series of the seasons it becomes apparent that, with the exception of summer, all the turned cooler and colder, respectively from the second half of the 16th century until the end of the 18th century. The picture is even simpler with regard to the precipitation time series, as all four seasons were predominantly wet from the second half of the 16th till the end of the 18th century. The 19th century brought a transitory period from a weather point of view, but there were cooling trends in all four seasons in the second half of the century. The average temperatures of springs, autumns and winters began to rise significantly from the turn of the 20th century, and trend which also established itself in summers in the second half of the 20th century.

All four seasons were mostly wet from the second half of the 16th century until the end of the 18th century. Precipitation levels decreased for all four seasons during the first half of the 19th century as springs and summers became dry. The Budapest time series shows that the trends of the precipitation time series for autumns, winters and springs were the same with regard to long-term century precipitation trends. Winters, springs and autumns turned wetter in the first half of the 20th century compared to the second half of the 19th century, but there is a strong drying trend in the second half of our century which relates to all three of these seasons. The curve of the summer precipitation time series goes in the opposite direction of that for the other three seasons for this one hundred and fifty years. The wet summers in the second half of the 19th century were followed by significantly drier seasons in the first half of the 20th century, while the second half of our century became wetter again.

c.

The climate regime of the Little Ice Age characterised by cool and wet weather determined the climate in the Carpathian Basin from the second half of the 16th century until the end of the 18th century, as shown by the temperature and precipitation time series for the whole year. Good proof of the water-balance change is that water-level of Lake Balaton was 4 m higher that period than nowadays. The following one hun-

dred and fifty years, from the first half of the 19th century until the middle of the 20th century, exhibited weather of a transitory nature, during which milder and cooler, and wetter and drier decades followed one another. The climate regime of the recent warming period characterised by warm and dry weather appears to develop at the middle of the 20th century.

d.

The danger of the recent warming increases, while forecasting its rate and ultimate intensity becomes more difficult, due to the fact that it is the result of both natural environmental processes and industrial activities. The issue is further complicated as the effects of these two factors effectively reinforce each other. In summarising the climate changes by century over the last two thousand years, one can venture to state that the recent warming trend that can be attributed to natural-environmental reasons would normally last for about 300-500 years, of which 140 years have already passed. However we do not have the data that would be required to properly factor in the past and present anthropogen effects, nor can the effects of future human activity, on the process of climate change be properly estimated. My research results imply that it is advisable to prepare for a climate characterised by warming and drying trends in the foreseeable future. Furthermore the implication is clear that we should expect that the frequency of winter half-year warm anomalies and the summer half-year dry anomalies will probably rise as well. It is these circumstances that will presumably determine the vital conditions of people living in the Carpathian Basin for a long to come.

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APPENDIX

Temperature indices of Hungary

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Win	Spr	Sum	Aut	Year
1500																	
1501											-1					-1	-1
1502																	
1503																	
1504																	
1506																	
1507			-2	-2	-2									-2			-2
1508						-1	-1	-1							-1		-1
1509																	
1510																	
1511																	
1512			-1											-1			-1
1513																	
1514																	
1515																	
1516							1	1	1	1	-1				1	1	1
1517																	
1518																	
1519																	
1520																	
1521							0								0		0
1522										-1						-1	-1
1523					1									1			1
1524																	
1525			-3											-2			-2
1526							0	0		0					0	0	0
1527																	
1528																	
1529							0	0		-2	0				0	-1	-1
1530										1	-1					0	0
1531																	
1532			0	0	0	0	0	-1						0	0		0
1533																	
1534				-2										-2			-2
1535																	
1536							0									0	0
1537																	
1538																	

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Win	Spr	Sum	Aut	Year
1539	2									-1			2			-1	0
1540				2										2			2
1541					2	1	1							2	1		2
1542																	
1543			-2							0				-2		0	-1
1544											-1					-1	-1
1545																	
1546																	
1547																	
1548																	
1549				3	1	1	1	1						2	1		2
1550						0				-1					0	-1	0
1551					2	2	2		-3					2	2	-2	1
1552							-1		0	-1					-1	0	0
1553			-1							2				-1		2	1
1554																	
1555	2	2											2				2
1556				2			2	-1						2	1		2
1557										-1			-3			-1	-2
1558												-3					
1559			1	-1	-1								0	-1			0
1560	-3				-1							0	-3	-1			-2
1561				-1									2	-1			1
1562										2		2	2			2	2
1563												2	-1				-1
1564	1				-1	0	0		0	0		-1	0	-1	0	0	0
1565	-2	-3	-3	-2		-1	0	0		-1	-1	-2	-3	-3	0	-1	-3
1566				1	0		0		-1	-1			2	0	0	-1	0
1567	-2	-3					0	0				2	-3		0		-2
1568	2									0		0	2			0	1
1569						0									0		0
1570																	
1571	1												1				1
1572																	
1573																	
1574																	
1575		-3											-2				-2
1576																	
1577																	
1578						0									0		0
1579		0	1	0									0	0			0
1580			0		0		1	1	1					0	1	1	1

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Win	Spr	Sum	Aut	Year
1581																	
1582																	
1583		2											2				2
1584																	
1585		0	0	0	3	2	0						0	2	1		1
1586			-1											-1			-1
1587																	
1588																	
1589												1					
1590	1	1											1				1
1591																	
1592												0					
1593							0	0				-1	0		0		0
1594	-2	0	-1										-2	-1			-2
1595							1	-1			-2				0	-2	-1
1596			0						0	0				0		0	0
1597			-1						-1	-1	-2			-1		-2	-2
1598	1		-1							-1	0		1	-1		0	0
1599											-1					-1	-1
1600									0	-1	-2	-1				-2	-1
1601	-3				-1				-1	-1	-1	-1	-2	-1		-1	-
1602		1			-1		-1				-1		0	-1	-1	-1	1
1603		-1							-1		-1	1	-1			-1-1	
1604										0			1			0	0
1605							0								0		0
1606	-1					-2							-1		-2		-2
1607	2	2					3						2		2		2
1608	-1			-1									-1	-1			-1
1609																	
1610	-1	-1		-1									-1	-1			-1
1611									-1							-1	-
1612	0	-1	0						0			2	0	0		0	0
1613	1							0		-1			2		0	-1	0
1614			-1	0						-3				0		-2	-1
1615					-1						0			-1		0	0
1616					-1	0								-1	0		0
1617		1											1				1
1618						0	0		2	0					0	1	1
1619		-1	0		-1	3			-1	0	0	-1	-1	-1	2	0	0
1620								0					-1		0		0
1621	-1						0	0					-1		0		0
1622		-1	-1					2					-1	-1	2		0

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Win	Spr	Sum	Aut	Year
1623																	
1624				1										1			1
1625					-1									-1			-1
1626																	
1627				1		0		0			1			1	0	1	1
1628							0					-1			0		0
1629				-1	-1								-1	-1			-1
1630										-1		-1				-1	-1
1631		0								-1			-1			-1	-1
1632				-1							-2			-1		-2	-2
1633					-1			0						-1	0		0
1634					0						-3			0		-2	-
1635					-2	-1					-1			-2	-1	-1	-2
1636	1	-1	0	1	1	0	0	0	0	-1	-1	-1	0	1	0	-1	0
1637	0	-1	-1	-1	1	1	1	2	-1	0	-1	0	-1	0	2	-1	0
1638	-1	0			0	0	1			-1	0	-1	-1	0	0	0	0
1639	0			0	0	0	1	0	2	-1	1		-1	0	0	1	0
1640	0	0	-1	-1	0	0	1	0	1	1	-1		0	-1	0	0	0
1641	-3	0	-1	1	-1	0	0	-2	0	-1	0	3	-2	0	-1	0	-1
1642	2	-1	-1	-1	-2	1	0	-1	0	0	0	-2	2	-2	0	0	0
1643	1	0	-1	-1	0	0	0	1		-1	-1	0	0	-1	0	-1	-1
1644	-1	0	0	0	-1		1	0	2	-1	-1	0	0	0	1	0	0
1645	-2				0	0	0	1	1	0		-1	-2	0	0	0	-1
1646			0					0			0		-1	0	0	0	0
1647								-1							-1		-1
1648	0		0									-1	0	0			0
1649									0	0	0					0	0
1650				-1	-1		0			1	1	1		-1	0	1	0
1651			-2	0	1									0			0
1652	0	-3	-3					0		0		0	-2	-2	0	0	-2
1653	0	1	-1						0	0	0		0	-1		0	0
1654			-1		0		0	0	-1		0	-1		0	0	0	0
1655			-2	-1		0			0				-1	-1	0	0	-1
1656	-2			0	0	0		0					-2	0	0		-
1657	0						0	0	1	0	1	1	0		0	1	0
1658	-1	-1		1		0		0	0			0	0	1	0	0	0
1659		1	-1	-1	0		0	0	-1			-1	0	-1	0	-1	0
1660		-2		0	0	0	0				-1	-1	-2	0	0	-1	-1
1661	1				-1			3				-1	0	-1	2		0
1662					-1	0	0	0		-1		0	-1	-1	0	-1	-1
1663		1	1	0	-2	1	0	0	0	0		0	0	-1	0	0	0
1664	-1	1	0	-1	-1	0	0	1	0	-1	1	1	0	-1	0	0	0

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Win	Spr	Sum	Aut	Year
1665	-1	0	-1	-1	1		0	0	1	0	-1		0	-1	0	0	0
1666	0	-1	-2	0	0	0	0	0	0	-1		1	0	-1	0	0	0
1667	-1	0	-1	0	0	0	0	0	1	0	1	-1	0	0	0	1	0
1668	0	1	0	-2	-1	1	0	0	0		1		0	-2	0	0	-1
1669	-3	1	1	-1	0	1	0	0			0	0	-1	0	0	0	0
1670		-1		0		0	0	-1				0	0	0	0		0
1671	1	-1	-1	0			-1						0	0	-1		0
1672					-1				0			1		-1		-1	-1
1673	1			0			0						1	0	0		0
1674		-1	1				-1				-1		-1	1	-1	-1	-1
1675			-1	-1	-2		-1	-1			0	1		-2	-1	0	-2
1676	0	0	0	-2		0					-1	0	0	-2	0	-1	-1
1677	1	1	-1	0	-1	0	1	0	-1	0	0	0	1	-1	0	0	0
1678	1	1	0	-1	0	1	1	2	1	1	1	1	1	0	2	1	1
1679	0	-1	1	0	-1	0	1	1	0	0	-1	-1	0	0	1	0	0
1680	-1	-1	0	1	1	1	1	1	1	1	-1	-1	-1	1	1	0	0
1681	-1	1			0	0	0						0	0	0		0
1682						1	1	1						0	1		1
1683	-1	-1	-2	0	1	-1	2	0		0		1	-1	0	0	0	0
1684	-2	-2		0		1	1		0	1	1	2	-2	0	1	1	0
1685	-3	-3	-2	1	1	1		0	-2	0	0	1	-2	-1	0	-1	-2
1686	1	0	2	-1	-1	-1			1	0	-2	-1	1	0	-1	0	0
1687				-1	0	0	0		1	0	1		-1	0	0	1	0
1688			-1	-1	0	1	2	1	1	-1		1		-1	2	0	0
1689		-2		1	-1	1	0	1	0		0	1	0	0	1	0	0
1690	0		-1		0	1		0	-1				0	0	0	-1	0
1691	1	-1	-2	-1	-1	-1	0	0	-1	-1	-1	1	0	-2	0	-1	-1
1692	-1	0	-1	0	0	0	0		1	0			0	0	0	0	0
1693	1	2	0	0		0	0	0	0	0	2	1	2	0	0	1	1
1694	-2	-1	-1	0	0	1	-1	1	-1	0	0	1	-1	0	1	0	0
1695			-2	0	0	-1	-1		-1	0	-1	-1	1	-1	-1	-1	-1
1696	1	1	-1	-2	-1	0	-1			1	1	0	0	-2	0	1	0
1697	-2	-2	-2	1	1	0	0			-1		-1	-2	0	0	-1	-1
1698		-1	-1				0	-1			-1		-1	-1	0	-1	-1
1699	1		-1					0	0				1	-1	0	0	0
1700	0	0	-1	-2	0	-1	0	-1		0	0		0	-2	-1	0	-1
1701	0	0		-1			3	3	2	2	1		0	-1	3	2	2
1702	1	3	1	-1	0	-1	1	1	-1	-1	-1	-1	2	0	0	-1	0
1703	1	0	1	1	2	2	-1	-2	2	0	1	0	0	2	-1	2	1
1704	-1	1	-1	1	-1	0	1	1	1		0	0	0	0	1	0	0
1705	-1	-2	-1	0	-1	-1	0	2	-2	1	1	1	-2	-1	1	0	-1
1706	-1	1	-1	1	-1	1	3	2	1	1	1	1	0	0	3	1	2

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Win	Spr	Sum	Aut	Year
1707	0	1	-1		-2	2	1	-2	1	0	0	1	1	-2	1	0	0
1708	1	2	1	0	0	-1	-1	1	2	0	2	0	2	0	-1	2	1
1709	-2	-2	-1	1	-1	1	1	1	0	0	0	-1	-2	0	1	0	0
1710	-1	-1	2		1	3	3			-1		-1	-1	2	3	-1	1
1711	-1	0		0	3	-1	1	-1	1	0	0	1	-1	2	0	0	0
1712	-1	0	-1		-1	-2	-2	-1					0	-1	-1		-1
1713	1	2	-1	-1	-1	-1	-1	-1	-1	-1	-1	0	2	-2	-1	-1	-1
1714													0				0
1715			0	0	-1									0			0
1716	1		-1	-2	-1			-1	-1	-2			1	-2	-1	-2	-2
1717	-1	1	1	-1	1	0	1	1	0	0	-1	-1	0	0	1	0	0
1718	-1	-1	0	0	0		0		-1	0	1	1	-1	0	0	0	0
1719	0	1	0	-1	-1	-1	1	1	0	-1	-1	-1	1	-1	0	-1	0
1720	1	-1	-1	-1	0	-1	-1	0	-1	-1	0	0	0	-1	-1	-1	-1
1721	1	0	0	0	-1	0				-1		1	0	0	0	-1	0
1722		1	0	-1	-1	1	0	0	-1	1	0	0	1	-1	0	0	0
1723	-1	-1	-1	-1	-2	-1	0	0	0	-1	-1	0	-1	-2	0	-1	-1
1724	1	1	-1	0	-1	0	0	1	0	1	1	-1	1	-1	0	1	0
1725	-1	-2	-2	-1	-1	1	1	-2	0	0	0	0	-2	-2	0	0	-2
1726	-1	0	-1	0	2	2	0	-1	-1	-1				1	1	-1	0
1727	2	1	-1	-1	0	0	0	-1	-1	0	-1	1	2	-1	0	-1	0
1728	1	-1	2	1	0	1	0	0	1	0	0	-1	0	2	0	0	1
1729	0	1	0	0	-1	1		-1	0				0	0	0	0	0
1730		-1	1	1	-1	-1	0	1	-1	-2	-2	0	-1	0	0	-2	-1
1731			-2			0			0				0	-1	0	0	0
1732						0				-1		-1			0	-1	-1
1733	0	0			-1	-1						1	0	-1	-1		-1
1734	1	1		-1				0		0	-1	0	1	-1	0	0	0
1735	1		1		0	0					-1	-1	0	0	0	-1	0
1736	1				-1			0	0				0	-1	0	0	0
1737			-1	-2	-1	0								-2	0		-1
1738					-1					0		1		-1		0	0
1739			0	-1		-1				-1	-1	0	1	0	-1	-1	-1
1740	-2	-2	-1	-2	-1	0	0	0	0	-1	0	0	-2	-2	0	0	-2
1741	1	1	-1	-1	0	0	0	0	-1			-1	1	-1	0	-1	0
1742	0		-1	-1			0		0	1	-1	0	0	-1	0	0	0
1743	-2		0	-1	0	0	0						-1	0	0		0
1744	-1	-1	0	2	0	0			0			0	-1	1	0	0	0
1745	-2	-1	1		0			0	-1				-2	0	0	-1	-1
1746			-1	0	-1	0								-1	0		-1
1747	0	1	-1	-1		0	-1					-1	0	-1	0		0
1748			-1	-1	1		0						-1	0	0		0

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Win	Spr	Sum	Aut	Year
1749		-1	-1										-1	-1			-1
1750								-1		0					-1	0	0
1751		1		0		0		0	0	-1	-1	1	1	0	0	-1	0
1752		0											0				0
1753			-1	0	-1		0		0		0			-1	0	0	0
1754	-1	-1	-1	0			0					-2	-1	0	0		0
1755	-2		0	0	0	2		0					-2	0	1		0
1756		0	0	-1	-1								0	-1			0
1757									0			1				0	0
1758									0		0	0	1			0	0
1759			-1	-2		0	0	0		1	-1		0	-2	0	0	-1
1760			-2	-1	-1				1			1		-2		1	0
1761	1						-2	-1	1	0			1		-2	0	0
1762	0	0	-1		-1	0	0					-2	0	-1	0		0
1763	0	2	-2	-1			3	2		0	0	0	0	-2	3	0	0
1764	2	2		-2	0	-1			0	0	0	1	2	-1	-1	0	0
1765	1	0	1	-1	-1	0	0	1	1		-1	-1	1	0	0	0	0
1766	0	-1	-1	0	0	-1	0	0	0	0		0	-1	0	0	0	0
1767	-1	0	-2	0	-1	-2		-1			1		0	-1	-2	1	-1
1768	-1	-1	-2	-1	-1				0	1	1	1	-1	-2		1	-1
1769	1	0	1	-1	-1	0					0	-1	1	0	0	0	0
1770	0	0	-1	-1					2	0	0	1	0	-1		1	0
1771	2	0	-1	-2	1	-1	0	-1	1		-1		1	-1	-1	0	0
1772	2	1	-1				0	0	0				2	-1	0	0	0
1773			-2	-1	1		0		1		0	1		-1	0	0	0
1774	-1	0	0	1	0	0	1		-1	-1	-1	-1	0	0	0	-1	0
1775	0	1	-2	-2						-2	0	0	0	-2		-1	-1
1776	-1	2	1	-1	-1				0	0	0	0	0	0		0	0
1777	-1	0	0	-1	-1	-2		0	-1		1	0	0	-1	-1	0	-1
1778	1	-1	-1	-1	0	0	3	1	0	-1	-1	1	0	-1	2	-1	0
1779	-1	1	1	1	0	0	-1		1	0	0	0	0	1	0	0	0
1780	-1	-1	-1	-1	0	-1		-1	-1	0	1	0	-1	-1	-1	0	-1
1781	-1	-1	-1	-1	-1	-1	1	3	3	-1	0	-2	-1	-1	2	1	0
1782	-1	-1	-1	-1	0	1	3	3	-1	1	-2	-1	-2	-1	3	-1	0
1783	0	1	1	-1	0	1	2	0	-1	1	-1	-1	0	0	2	0	1
1784	-2	-1	-2	-2	-1	1	1	2	1	-1	0	0	-2	-2	2	0	-1
1785	-1	-1	-3	-1	-1	0	0	0	-1	-1	-1	0	-1	-3	0	-1	-2
1786	0	1	-1	-1	-1	-1	0	0	0	-1	0	0	0	-1	0	0	0
1787	0	-1	0	-1	-1	0	0	-1	0	-1	0	0	0	-1	0	0	0
1788	2	-1	0	-1	0	0	3	0	1	0	-1	-3	0	0	2	0	1
1789	-1	0	-1	-1	1	0	0	0	0	-1	-1	-1	-2	0	0	-1	-1
1790	-1	1	0	0	0	0	0	0	-1	0	1	1	0	0	0	0	0

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Win	Spr	Sum	Aut	Year
1791	1	1	1	1	-1	-1	1	2	-1	-1	-1	1	1	0	1	-1	0
1792	0	0	0	-1	-1	0	2	0	0	0	0	0	0	-1	1	0	0
1793	-1	0	-1	-1	0	-1	2	0	0	0	0	0	0	-1	1	0	0
1794	0	0	0	0	0	1	1	0	0	0	0	-1	0	0	1	0	0
1795	-1	-1	-1	0	-1	0	0	0	0	0	-1	0	-1	-1	0	0	-1
1796	1	1	-1	0	0		0	0	-1	-1	0	0	1	0	0	-1	0
1797	-1	1	0	0	3	1	2	0	2	0	0	0	0	2	2	1	2
1798	0	0	-1	0	0	0	1	2	1	-1	-1	-1	0	0	2	0	1
1799	-2	-1	0	-1	-1	-1	0	1	-1	0	-1	-2	-2	-1	0	-1	-2
1800	0	0	-2	0	1	1	1	0	-1	-1	0		-1	0	1	-1	0
1801			-1	1		-1	0	-1	0	0	0	1		0	-1	0	0
1802	0	-1		-2	0		2	0	0		1	2	0	-1	1	0	0
1803	-1	-1	1	1	1	0	0	0	0	0	1	-1	0	1	0	0	0
1804	2	0	-1	0	-1	0		0	0		-2	0	0	-1	0	-1	-1
1805	0	-1	1	0	-1		0					0	0	0	0		0
1806	1	2	-1	0		-1	1						1	0	0		0
1807	0		0	-1	0	0	1	2				0	0	0	2		1
1808	1		-1	0	0	0				0	-1	-1	0	0	0	0	0
1809	0	1	-1	-1		0	-1		-1	0		1	0	-1	0	0	0
1810	1	0	-1	-1	-1	-1	0	1	1	0		-1	1	-1	0	0	0
1811	-2	0	1	0	0	1	2	0	1		2	1	-1	0	1	2	1
1812	-1	1	0	-2	-1	0	0	0	-1	0	-1	-2	0	-2	0	-1	-1
1813	-3	-1	-1	0	0	0	-1	-1	0			0	-3	0	-1	0	-2
1814	1	-1	1	-1	-1	-1		0	0	-1		1	0	0	0	0	0
1815	0	1	-1	0	-1	0	0	0	-1	-1	-1	-1	1	-1	0	-1	0
1816	-1	-2	-1	-1	0	-1	-1		0	0	-1	0	-2	-1	-1	0	-2
1817	1	2	0	-1	1	2	2	1	1	0	1	1	1	0	2	1	2
1818	1	3	-1	0	0	0	0	-1	0	-1	-1	-1	2	0	0	-1	0
1819	-1	0	0	0	-1	0	-1	0	1	2	-1	1	-1	0	0	1	0
1820	0	1	-2	0	-1	-1	1	2	1	1	1	0	1	-2	1	1	0
1821	1	1	-1	1	0	-2	-1	0	0	0	2	1	1	0	-2	1	0
1822	2	1	-1	1	1	1	1	2	1	1	1	-2	2	0	2	1	2
1823	-1	0	1	-2	0	0	0	1	0	-1	0	1	-1	0	0	0	0
1824	2	2	-2	-2	-1	1	1	2	0	0	1	1	2	-2	2	0	-1
1825	2	1	-2	1	-1	-1	-1	0	-1	-2	1	3	2	0	-1	-1	0
1826	-2	-2	-1	-2	-2	0	0	0	0	1	0	1	0	-2	0	0	-1
1827	1	0	0	1	0	1	2	1	0	1	-1	1	1	0	1	0	1
1828	0	0	-1	0	1	1	-1	-1	0	-1	-1	0	0	0	-1	-1	-1
1829	1	-1	-1	0	-3	-1	0	0	0	0	-2	-2	0	-2	0	-1	-1
1830	-2	-2	-2	-1	3	1	3	2	1	0	0	1	-3	0	3	0	0
1831	0	0	-1	1	-1	-1	-1	-1	0	1	0	1	0	0	-1	0	0
1832	2	0	-1	-1	-1	-2	-1	0	0	1	0	0	1	-1	-2	0	-1

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Win	Spr	Sum	Aut	Year
1833	-2	0	-1	-1	2	2	-1	-2	-1	1	0	1	-1	0	-1	0	-1
1834	3	2	-2	-1	-1	3	3	3	2	0	0	1	3	-2	3	1	2
1835	1	2	-1	-1	-1	-1	1	0	0	1	-1	-1	2	-1	0	0	0
1836	-1	0	1	-1	-2	1	1	0	1	0	0	1	-1	-1	1	0	0
1837	1	-1	-1	0	-1	-1	-1	1	0	0	1	0	0	-1	-1	0	-1
1838	-1	0	-2	-1	-1	0	0	-2	2	0	0	1	0	-2	-1	1	-1
1839	1	1	-2	-2	-1	2	3	2	1	1	1	1	1	-2	3	1	1
1840	1	1	-2	-1	-1	-1	0	-1	1	-1	1	-2	1	-2	-1	0	-1
1841	1	-1	-1	1	1	1	2	2	0	2	1	2	-1	0	2	2	1
1842	0	-1	-1	-2	-1	0	-1	1	0	-1	0	1	0	-2	0	0	-1
1843	2	3	-2	-1	-1	-1	-1	-1	-1	0	1	2	3	-2	-1	0	0
1844	1	0	-1	-1	1	0	-1	-1	0	0	1	1	1	0	-1	0	0
1845	2	0	-2	0	-1	0	1	0	0	1	0	1	1	-2	0	0	0
1846	2	2	-1	-1	1	1	1	1	0	2	0	0	2	0	1	1	2
1847	1	1	-2	-1	1	-1	0	0	-1	0	0	1	1	-1	0	0	0
1848	-2	1	-1	-1	0	1	1	1	0	0	0	1	0	-1	1	0	0
1849	0	1	-1	-1	-1	0	1	-1	0	1	-1	0	1	-1	0	0	0
1850	-1	0	-2	-1	-1	1	1	2	-1	0	0		0	-2	2	0	0

Precipitation indices of Hungary

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Win	Spr	Sum	Aut	Year
1500																	
1501											1					1	1
1502																	
1503																	
1504																	
1505																	
1506																	
1507			1	1	1									1			1
1508						2	2	2							2		2
1509																	
1510																	
1511																	
1512			1											1			1
1513																	
1514																	
1515																	
1516							0	0	0	0	0				0	0	0
1517																	

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Win	Spr	Sum	Aut	Year
1518																	
1519																	
1520																	
1521							1								1		1
1522										1						1	1
1523					0									0			0
1524																	
1525			0											0			0
1526							1	2		1					2	1	1
1527																	
1528																	
1529							1	1		2	1				1	1	1
1530										0	2					1	1
1531																	
1532			-1	-3	-3	0	2	3						-3	3		0
1533																	
1534				1										1			1
1535																	
1536									1							1	1
1537																	
1538																	
1539	0									1			0			1	0
1540				-2										-2			-1
1541					0	0	0							0	0		0
1542																	
1543			1							2				1		2	1
1544											1					1	1
1545																	
1546																	
1547																	
1548																	
1549				-3	-1	-2	-2	-1						-2	-2		-2
1550						-1				0					-1	0	0
1551					-2	-2	-2		0					-2	-2	0	-2
1552							3		1	1					2	1	1
1553			0							0				0		0	0
1554																	
1555	0	0											0				0
1556				0			0	0						0	0		0
1557										0						0	0
1558												0					
1559			-1	1	1								0	1			0

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Win	Spr	Sum	Aut	Year
1560	0				0							0	0	0			0
1561				0									0	0			0
1562										-2		1				-2	-1
1563												0	1				1
1564	1				1	0	1		0	3		0	0	1	0	2	1
1565	0	0	0	0		1	1	0		1	1	0	0	0	1	1	1
1566				0	0		2		0	1			0	0	2	1	1
1567	1	0					1	0				1	0		0		0
1568	0									0		0	0			0	0
1569						1							0		1		0
1570																	
1571	1												1				1
1572																	
1573																	
1574																	
1575		0											0				0
1576																	
1577																	
1578						1									1		1
1579		1	0	0									1	0			0
1580			-2		1		-2	-2	-2					-1	-2	-2	-2
1581																	
1582																	
1583		0											0				0
1584																	
1585		-2	1	-1	-2	-2	1						-2	-1	-1		-2
1586			1											1			1
1587																	
1588																	
1589												1					
1590	0	0											0				0
1591																	
1592												1					
1593							1	1				0	1		1		1
1594	0	2	2										1	1			1
1595							0	0			0				0	0	0
1596			1						2	1				1		2	1
1597			1						2	1	1			1		2	1
1598	1		1							2	1		1	1		2	2
1599											0					0	0
1600									0	1	1	0				1	1
1601	0				1				0	0	1	1	0	1		0	0

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Win	Spr	Sum	Aut	Year
1602		0			0		0				1		0	0	0	1	0
1603		0							0		0	0	0			0	0
1604										1						1	1
1605							1								1		1
1606	0					1							0		1		0
1607	2	0					-3						1		-2		0
1608	0			0									0	0			0
1609																	
1610	0	1		0									0	0			0
1611									1							1	1
1612	1	1	1						0			0	1	1		0	1
1613	0							1		1			0		1	1	1
1614			1	3						1				2		1	1
1615					0						-1			0		-1	0
1616					0	-2								0	-2		-1
1617		1											1				1
1618						1	1		-1	1					1	0	0
1619		0	-1		0	-3			1	1	1	1	0	-1	-2	1	-1
1620								1							1		1
1621	0						1	1					0		1		0
1622		0	0					0					0	0	0		0
1623																	
1624				0										0			0
1625					0									0			0
1626																	
1627				0		1		1			0			0	1	0	0
1628							2					0			1		1
1629				1	0								0	0			0
1630										0		0				0	0
1631		1								0			0			0	0
1632				0							0			0		0	0
1633					1			-3						1	-2		-1
1634					-2						1			-2		1	-1
1635					2	1					1			1	1	1	1
1636	0	1	0	0	-3	0	0	1	1	1	1	1	0	-2	0	1	0
1637	1	1	1	0	0	-1	1	-2	0	1	1	0	1	0	0	1	1
1638	0	0			0	0	0			0	0	0	0	0	0	0	0
1639	0			0	1	1	0	1	-2	-1	0			0	1	-2	0
1640	0	0	1	0	-2	1	0	1	1	0	1		0	0	1	1	1
1641	1	0	1	0	1	0	1	0	0	0	2	0	0	1	0	1	1
1642	0	2	0	-1	0	0	1	0	1	-2	0	0	1	0	0	-1	0
1643	1	0	1	1	1	0	0	0		0	1	0	0	1	0	0	0

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Win	Spr	Sum	Aut	Year
1644	0	0	1	0	0		-1	1	-2	1	-1	0	0	0	0	-1	0
1645	0				1	1	0	1	1	0		0	0	1	1	0	1
1646			-1					1			1		0	-1	1	1	0
1647								2							1		1
1648	1		0									1	1	0			0
1649									1	2	2		1			2	1
1650				0	0		0			0	0	0		0	0	0	0
1651			1	0	0								0	0			0
1652	0	0	0					-3		1		-3	0	0	-2	1	0
1653	0	0	1						1	1	0		-1	1		1	0
1654			0		0		1	1	1		1	0		0	1	1	1
1655			2	0		1			1				0	1	1	1	1
1656	0			1	1	1		1					0	1	1		1
1657	0						0	2	0	0	0	0	0		1	0	0
1658	0	0		0		2		1	1			1	0	0	2	1	1
1659		0	1	0	1		1	2	0			1	0	1	2	0	1
1660		1		0	1	1	1				1	1	1	0	1	1	1
1661	0				0			0				0	0	0	0		0
1662					1	1	1	1		1		1	0	1	1	1	1
1663		0	1	1	1	2	1	1	1	1		1	0	1	2	1	2
1664	0	0	-2	-1	1	1	0	1	1	1	2	1	0	-1	1	2	1
1665	1	1	1	0	1		2	2	0	1	0		1	1	2		2
1666	0	1	1	1	1	-2	-2	1	1	1		1	0	1	-2	1	0
1667	0	0	1	1	1	2	2	2	1	1	0	1	0	1	2	1	2
1668	1	0	0	2	1	1	2	1	1		0		1	2	2	0	2
1669	0	0	-1	1	1	1	0	0			0	0	0	1	0	0	0
1670		0		1		1	1	1				1	0	1	1		1
1671	0	0	1	1			0						0	1	0		0
1672					0				1			0		0		1	0
1673	0			1			1						0	1	1		1
1674		0	0				1				1		0	0	1	1	1
1675			2	1	1		1	2			1	1		2	2	1	2
1676	-1	-1	-2	-2		1					1	1	0	-1	1	1	0
1677	0	1	1	1	0	1	0	0	0	2	1	1	1	1	0	2	2
1678	0	1	0	1	0	1	-1	-1	-1	1	0	0	1	0	0	0	0
1679	0	0	0	1	0	0	1	0	1	0	1	0	0	0	0	1	0
1680	0	1	1	0	1	1	0	1	0	0	1	1	0	1	1	0	1
1681	0	0			-1	-2	-2						0	-1	-2		-1
1682					-3	-2	0	0						-2	-1		-1
1683	1	0	0	1	0	0	-1	-2		1		1	0	0	-2	1	0
1684	2	1		-2		0	0		1	0	1	2	2	-2	0	1	1
1685	1	1	0	-1	0			0	0	1	1	1		0	0	1	0

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Win	Spr	Sum	Aut	Year
1686	-1	-2	0	-1	0	1			-2	-2	1	1	-1	0	1	-2	-1
1687				0	-1	-1	1		0	-1	0		1	0	0	0	0
1688			1	1	-1	0	-3	0	0	1	1	1		1	-2	1	0
1689		1	0		0	2	0	0	-1		2	1	1	0	1	0	1
1690	1		1		1	-2		1					1	1	-1	0	0
1691	1	0	0	1	0	2	1	-1	0		1	1	0	0	1	0	0
1692	1	1	1	0	1	1	1		-2	-1			1	1	1	-2	0
1693	1	0	0	1	-1	0	0	0	0	0	0	0	0	0	0	0	0
1694	2	1	0	1	0	1	1	-1	1	0	1	1	1	0	1	1	1
1695			0	0	0	1	1		2	0	0	1	1	0	1	1	1
1696	-1	-2	1	1	1	0	1			0	0	1	-1	1	0	0	0
1697	2	1	0	0	0	-1	1			1		1	2	0	0	1	1
1698		1	1				2	1			1		1	1	2	1	2
1699	0		0				1		1				0	0	1	1	1
1700	0	0	1	1	2	1	1	1		2	2		0	2	1	2	2
1701	0	0		0			-1	-2	-2	1	1		0	0	-2	0	-1
1702	1	-1	-1	0	0	1	0	0	-1	0	1	0	0	0	0	0	0
1703	0	0	0	0	-1	-1	1	1	0	1	0	0	0	0	0	0	0
1704	1	0	1	-1	-1	-2	0	-1	-1		-1	0	0	-1	-2	-1	-2
1705	-1	-2	1	1	2	1	2	-1	2	-1	0	0	-1	2	1	1	1
1706	0	0	1	-1	1	0	-1	0	0	0	1	1	0	0	0	0	0
1707	1	-1	2		2	-1	0	1	0	1	1	1	0	2	0	1	1
1708	1	2	1	1	-1	3	1	0	-2	0	0	1	2	0	2	0	2
1709	1	1	1	0	0	-1	-1	0	1	2	2	1	1	0	-1	2	1
1710	-1	0	-2		0	-3	-3			1		0	0	0	-3	1	-1
1711	1	0		1	0	1	0	1	0	1	1	0	0	1	1	1	1
1712	3	0	0		2	0	0	2					1	1	1		1
1713	0	2	0	2	1	1	1	1	0	1	1	1	1	2	1	1	2
1714													1				1
1715			-2	1	0									0			0
1716	1		0	-1	1			1	0	0			1	0	1	0	1
1717	-1	1	-1	-1	0	0	1	1	2	1	0	1	0	-1	1	2	1
1718	0	-1	0	-1	-1		-1		0	-1	1	0	0	-1	-1	0	-1
1719	1	1	1	2	1	-1	1	0	0	-1	0	0	1	2	0	0	1
1720	0	1	0	0	0	-1	0	2	2	0	0	1	0	0	1	1	1
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1722		0	0	0	0	-1	-1	-1	1	1	1	1	0	0	-1	1	0
1723	1	0	1	1	0	1	1	1	0	0	0	1	1	1	1	0	1
1724	0	0	1	1	-1	-2	0	-1	0	0	0	0	0	0	-2	0	-1
1725	1	0	1	0	1	1	0	2	1	1	0	1	0	1	2	1	1
1726	1	1	0	0	-2	-2	0	0	-2	0			1	-1	-1	-1	-1
1727	1	1	1	1	-2	1	2	2	2	1	1	0	1	0	2	2	2

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Win	Spr	Sum	Aut	Year
1728	0	0	0	0	1	-1	-2	0	0	2	1	2	0	0	-2	2	0
1729	1	0	0	0	1	0		1	2				1	0	0	1	1
1730		0	1	1	1	2	1	1	1	1	1	2	0	1	2	1	1
1731			0			1			1				1	0	1	1	1
1732						0				1		1			0	1	0
1733	0	0			0	0						0	0	0	0		0
1734	0	0		1				2		1	0	0	0	1	2	0	1
1735	0		0		2	1					0	-1	0	1	1	0	1
1736	0				0			1	1				0	0	1	1	1
1737			0	2	1	1								2	1		1
1738					0					-1		0		0		-1	0
1739			0	1		0				0	0	1	0	0	0	0	0
1740	0	0	0	0	1	2	1	2	-1	1	0	1	0	0	2	0	1
1741	0	0	0	0	-1	1	1	1	0			0	0	0	1	0	0
1742	0		1	1			-2		1	1	1	1	0	1	-2	1	0
1743	-1		0	1	1	1	-1						0	1	0		0
1744	0	-1	1	-2	-1	1			1			1	0	-1	1	1	0
1745	0	0	0		2			-1	0				0	1	-1	0	0
1746			1	-1	-1	-2								0	-2		-1
1747	0	0	1	0		1	0					0	0	1	0		0
1748			1	0	0		1						0	0	1		0
1749		0	0										0	0			0
1750								0		1					0	1	0
1751		0		1		0		2	2	1	1	0	0	1	1	2	1
1752		-1											0				0
1753			0	1	0		1		1		1			0	1	1	1
1754	2	0	0	1			0					0	1	0	0		0
1755	0		0	-1	-1	-2		0					0	-1	-1		-1
1756		0	0	1	1								0	1	-1		0
1757									1			1				1	1
1758									2		1	1	1		0	2	1
1759			0	0		-1	-2	1		1	0		1	0	-1	0	0
1760			0	-2	-2				0			0		-2		0	-1
1761	0						0	0	0	2			0		0	1	0
1762	1	1	1		0	-1	-1					-2		1	-1		0
1763	1	-2	0	0			-2	-2		1	1	1	-1	0	-2	1	-1
1764	1	0		0	0	0			1	2	2	2	1	0	0	2	1
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1766	0	0	1	1	1	0	1	0	0	0		1	0	1	0	0	0
1767	0	1	2	1	1	2		2			0		1	2	2	0	2
1768	0	0	0	0	0				2	0	0	0	0	0		1	0
1769	0	1	0	0	0	1					0	1	0	0	1	0	0

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Win	Spr	Sum	Aut	Year
1770	0	0	1	0					0	2	1	0	0	0		2	1
1771	2	0	0	0	-1	2	1	1	0		0		1	0	2	0	1
1772	1	0	0				0	0	-1				0	0	0	-1	0
1773			0	0	0		0		0		2	2		0	0	1	0
1774	2	1	0	-1	0	1	-1		0	1	0	1	2	0	0	0	1
1775	1	0	0	0						2	2	2	1	0		2	1
1776	0	2	1	0	0				-2	-2	1	0	2	0		-2	0
1777	1	1	1	1	0	2		0	0		0	1	1	1	1	0	1
1778	1	-1	0	0	0	1	0	0	1	1	-1	2	0	0	0	0	0
1779	0	0	0	-1	-1	0	0		-2	-1	2	2	1	-1	0	-1	0
1780	0	0	0	1	1	2		1	2	1	-1	2	1	1	2	1	2
1781	0	2	0	-2	-1	2	0	-2	-2	1	1	0	2	-2	0	0	0
1782	0	0	2	1	0	-2	-2	-2	2	1	2	1	0	2	-2	2	1
1783	1	0	0	-1	-1	0	0	1	1	-1	-1	0	1	-1	0	0	0
1784	1	1	0	1	0	0	-1	-2	-1	1	1	1	1	0	-2	0	0
1785	0	0	0	1	0	1	1	1	0	2	1	2	0	0	1	2	1
1786	1	1	0	1	1	2	1	1	0	1	1	1	2	1	2	1	2
1787	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1
1788	2	0	0	-1	0	0	-2	-2	0	1	1	2	1	0	-2	1	0
1789	0	1	1	0	0	0	1	1	1	0	1	0	1	0	1	1	1
1790	1	1	0	-1	0	-1	0	-1	0	1	1	2	1	0	-1	1	0
1791	1	0	1	0	0	1	-1	-2	-1	0	1	1	1	0	-1	0	0
1792	1	1	1	-1	0	1	1	0	1	1	0	1	1	0	1	1	1
1793	1	-1	0	-1	0	1	0	1	1	0	0	1	0	0	1	0	0
1794	-1	0	-3	-2	0	1	-1	-2	2	1	1	1	0	-3	-1	2	-1
1795	1	0	0	0	0	-1	1	0	-1	0	1	1	1	0	0	0	0
1796	0	1	1	0	0		0	0	0	-1	1	0	1	0	0	0	0
1797	0	1	1	1	-2	-1	-2	-1	-1	0	0	0	0	0	-2	0	-1
1798	1	1	1	-1	0	0	1	-1	-1	-1	0	1	1	0	0	-1	0
1799	0	0	0	1	0	0	1	1	1	1	0	1	0	0	1	1	1
1800	1	0	0	1	-1	0	-1	-1	0	-1	0		1	0	-1	0	0
1801			0	0		2	2	2	2	1	1	1		0	2	2	2
1802	0	0		-2	-1		0	0	-2	-3	0	0	0	-2	0	-3	-2
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1804	0	2	1	1	1	1		-2	1		0	0	1	1	-1	0	0
1805	-1	0	1	0	0		1						0	0	1		0
1806	0	0	0	0		0	0						0	0	0		0
1807	0		-1	0	-2	1	-2	-2				0	0	-2	-2		-2
1808	0		0	-1	-3	1				2	0	0	0	-2	1	1	0
1809	0	1	0	1		-1	1		2	2		1	0	1	0	2	1
1810	0	0	0	0	0	0	-1	-2	-2	-1		0	0	0	-2	-2	-2
1811	0	0	0	0	-2	-2	-2	-2	-2		0	0	0	-1	-2	-1	-2

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Win	Spr	Sum	Aut	Year
1812	0	0	0	-1	0	-1	-1	0	0	1	0	0	0	0	-1	0	0
1813	0	0	1	-2	0	0	1	1	2			1	0	0	1	1	0
1814	0	0	-1	0	1	2		1	0	0		0	0	0	2	0	0
1815	0	0	0	1	0	1	1	1	1	1	0	0	0	0	1	1	1
1816	1	0	1	0	1	1	1		0	0	1	0	0	1	1	0	1
1817	0	0	0	0	-1	0	-2	0	0	1	1	1	0	0	-1	1	0
1818	0	0	0	-1	-1	-2	-1	1	2	0	0	0	0	-1	-1	1	0
1819	0	0	-1	-1	0	1	0	1	0	0	1	0	0	-1	1	0	0
1820	0	0	0	0	0	2	-1	-2	-1	1	1	0	0	0	-1	1	0
1821	-1	-2	0	1	0	2	1	0	0	1	0	0	-1	0	2	0	0
1822	-1	0	1	-1	-2	-2	-2	-2	-1	-1	-1	0	0	-1	-2	-1	-2
1823	1	1	-2	1	0	1	0	-1	-1	-2	0	0	1	-1	0	-2	-1
1824	0	0	0	-1	0	0	-1	-2	-2	-1	0	0	0	0	-2	-2	-2
1825	0	0	-1	-2	-2	1	2	1	1	2	0	0	0	-2	2	1	0
1826	0	0	0	0	2	0	0	-1	-1	0	0	1	0	1	0	0	0
1827	0	0	0	-1	-1	-1	-2	-1	-1	-1	0	0	0	-1	-2	-1	-2
1828	0	0	0	0	-1	1	1	1	0	0	0	0	0	0	1	0	0
1829	0	0	1	-1	2	1	-1	-1	0	1	1	1	0	1	0	1	1
1830	1	1	0	0	0	-1	-2	-2	-1	-1	0	1	1	0	-2	-1	-1
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1832	0	-1	-2	0	1	1	-1	-1	-1	-2	0	1	0	0	-1	-2	-1
1833	0	0	1	0	-2	-3	2	2	2	0	1	1	0	0	0	2	0
1834	0	0	0	-1	-1	-3	-3	-3	-2	0	0	0	0	-1	-3	-1	-2
1835	0	0	0	0	1	1	0	-1	0	0	0	-1	0	0	0	0	0
1836	-1	0	0	-1	0	-2	-2	-2	-2	-1	1	1	-1	0	-2	-1	-2
1837	0	0	0	0	2	3	2	-1	0	0	0	0	0	1	2	0	1
1838	3	1	0	1	0	1	0	0	0	0	0	0	2	0	0	0	1
1839	1	1	1	1	2	-2	-3	-2	0	0	0	1	1	2	-3	0	0
1840	0	0	1	0	-1	0	1	1	0	2	1	0	0	0	1	2	1
1841	0	0	0	-1	-2	-1	-1	-2	0	0	0	2	0	-2	-2	0	-2
1842	1	0	0	-2	1	-1	-2	-2	0	1	1	1	1	0	-2	1	0
1843	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	0	0
1844	0	0	0	0	-1	1	0	1	1	0	0	0	0	0	1	0	0
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1847	0	0	0	0	0	1	0	1	1	2	0	0	0	0	1	2	1
1848	0	0	0	0	1	1	0	-1	0	1	0	-1	0	0	0	0	0
1849	0	0	0	0	1	0	-1	1	0	0	1	0	0	0	0	0	0
1850	1	0	0	0	1	-1	-1	-2	0	1	1		0	0		1	0

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