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Enriching the historical meteorological information using Romanian newspaper reports

Short title: Historical meteorological information in Romania

S Cheval (1, 2, 3)*, A Haliuc* (3, 4, 5), B Antonescu (6), A Tișcovschi (7), M Dobre (7), F Tătui (7), A Dumitrescu (2, 3), A Manea (2), G Tudorache (7,8), A Irimescu (2), M-V Birsan (2), C Mock (9)

(1) "Henri Coandă" Air Force Academy, Faculty of Aeronautical Management, Brașov, Romania

(2) National Meteorological Administration, Bucharest, Romania

(3) Research Institute of the University of Bucharest, University of Bucharest, Bucharest, Romania

(4) Charles University, Faculty of Mathematics and Physics, Prague, Czech Republic

(5) University of Suceava, Faculty of History and Geography, Suceava, Romania

(6) National Institute for Research and Development in Optoelectronics, Bucharest, Romania

(7) University of Bucharest, Faculty of Geography, Bucharest, Romania

(8) National Institute of Hydrology and Water Management, Bucharest, Romania

(9) University of South Carolina, Department of Geography, Columbia, United Stated of America

*Correspondence:

Aritina Haliuc, Research Institute of the University of Bucharest, 36-46 Bd. M. Kogalniceanu, 5th District, 050107 Bucharest, Romania, E-mail: aritina.haliuc@icub.unibuc.ro aritinahaliuc@gmail.com

Sorin Cheval, "Henri Coandă" Air Force Academy, Strada Mihai Viteazul 160, Brasov 500187, Romania, E-mail: sorin.cheval@afahc.ro; sorincheval@yahoo.com

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Abstract. Data recovery and climate reconstruction are an important support for climate change research, as they provide information from periods and areas with sparse meteorological networks. Various sources are currently in use for obtaining valuable evidences about the climate of the past, e.g. historical archives, ship logs or church documents. This study exploits newspaper reports in order to enrich the historical meteorological information over the territory of Romania, from the last two decades of the 19th century. The digital archive of three newspapers (*România Liberă, Gazeta de Transilvania and Foaia Poporului*) was investigated and the meteorological information was extracted and aggregated into a database containing 2132 unique entries. Each entry represents a meteorological event and several associated characteristics, such as date and location, impact and source. A verification procedure consisting of comparison with available measurements from the nearby weather stations was applied in order to validate the entries. The results show that the meteorological information was often present in the newspapers of the epoch. Some climatic features could be retrieved (i.e, seasonality of extreme events, thermal and precipitation characteristics). This paper demonstrates the potential of the collected information to enhance the understanding of the climate and climate perception at the end of the 19th century in Romania.

Introduction

In the last decades, the technological progress and the increasing societal needs have demanded unprecedented spatial coverage of meteorological data, at high temporal resolution at daily timescales. The combined use of remote sensing products and ground-based sensors, the evidence retrieved from citizen observatory and media (Muller et al., 2015; Groenemeijer et al., 2017), have made the meteorological information accessible globally and in real-time. Special attention has been devoted to understanding the behaviour of extreme climatic events (e.g. drought, floods, heat waves), which are expected to occur more frequently in many regions around the world (Fischer and Schär, 2009; Seneviratne et al., 2012; Rajczak et al., 2013). High spatial and temporal resolution weather information can help improve the forecasting and to mitigate the impacts of these extreme climate events, (Seneviratne et al., 2012). However, the long-term instrumental data series necessary for climate analysis are not always currently available because of, for example, sparse meteorological networks, unsystematic development of the monitoring networks, lost archives or missing records.

As most of the national meteorological networks were established in the 19th and 20th century (Jones, 2001; Böhm et al., 2009), efforts have been directed to document past weather and weather-related events using natural archives (e.g. tree rings, lake and fluvial sediments) (Jones and Mann, 2004; Büntgen et al., 2006, 2011; Trouet, 2014; Cook et al., 2015) and written records (Brázdil, 2005; Macdonald et al., 2007; Jones, 2008; Pfister et al., 2008), in order to reconstruct climate of certain epochs.

Historical written archives include manuscripts, books, diaries, newspapers, navigation logs, clerical documents, pictures/drawings or inscriptions, which describe specific meteorological events or their impact (Brázdil et al., 2009; Pfister et al., 2008; Brönnimann et al., 2018). These archives are useful tools for reconstructing the weather conditions and climate of the last centuries based on direct and indirect observation and on human perceptions. To fill the spatial and temporal gaps in meteorological data, indirect indicators (i.e. proxies from natural archives) and historical documents have been successfully used, balance with high resolution, direct climate information (Battipaglia et al., 2010; Büntgen et al., 2011; Brönnimann et al., 2018; Mock, 2012). Historical archives also provide the opportunity to calibrate and validate the climate reconstructions with instrumental datasets and to unveil the climate-society relationship over time (Pfister et al., 2018).

Across Europe, climate reconstructions based on historical documents have a long tradition especially in Switzerland, Spain, Czech Republic, and Germany where efforts have been directed to compile databases and source collections (e.g., Euro-Climhist - https://www.euroclimhist.unibe.ch/en/, Daux et al., 2012, McCormick et al., 2012). However, only few studies have addressed climate reconstructions based on historical documents in Eastern Europe. For example, using a large collection of historical documents retrieved by Antal Réthly, professor and director of the former National Meteorological and Earth Magnetism Institute of Hungary (Réthly, 1962, 1970, 1998, 1999), Bartholy et al. (2004) reconstructed some detailed characteristics of the climate within the Carpathian region between the 12th and 19th century (e.g. the seasonal frequency of warm and cold conditions). Kiss (2009) emphasized some shortcomings of the Réthly database (e.g. dating of the events, location) but these are common limitations for such large compilations of data.

In Romania, Topor (1964) compiled historical documents (i.e. Latin sources, annals, chronicles, narratives, clerical documents, newspapers) covering roughly the past two millennia and investigated the multi-centennial frequency of dry and wet periods in the region and their effects on agriculture and society (Figure 1). Corfus (1975) published a small collection of natural (i.e. weather, floods, earthquakes, insect invasion) and social events (i.e. conflicts, education, outbreaks) from the 17th century onwards based on old manuscripts available from the Library of Romanian Academy. Cernovodeanu and Binder (1993) indirectly analysed the climate information related to Transylvania (i.e. north-western and central part of Romania), as retrieved from historical documents of Middle Age reported mainly in the Réthly database. More recently, Dudas (1999) collected information about climatic anomalies and other events from documents issued between 1501 and 1900 for the central part of the country (i.e. Transylvania).

Newspaper and magazine articles as a proxy for primary source historic climate reconstruction have been successfully employed in climate reconstructions in different parts of the world, such as Europe (Brázdil et al., 2005), Great Britain (Taylor et al .,2015), Ireland (Murphy et al., 2017), Spain (Añel et al., 2017) and Hawaii (Businger et al., 2018). When the information is carefully selected and properly interpreted (e.g. considering an appropriate level of uncertainty or validating with other sources), its scientific utility can be supplementary in historical climatology and physical geography at different timescales. For example, focussing on information retrieved from regional newspapers issued in 2006 and 2011, Taylor et al. (2015) enriched the UK National Landslide Database with 111 records.

This paper demonstrates the climate data potential perspective based on articles/reports from three Romanian newspapers, published at the end of the 19th century. After the Introduction (Section 1), this article is structured in four sections. Section 2 describes the characteristics of the newspaper data used. A brief description of the meteorological measurements and network and the climate of Romania of the analysed period is included in section 3. Section 4 contains the results and discussions, and section 5 summarizes the article and outlines further research directions.

1. Newspaper data

Meteorological information was manually collected from the digital collections of three newspapers issued at the end of the 19th century in Romanian, (1) *România Liberă* (RL), issued at Bucharest (Romania), (2) *Gazeta de Transilvania* (GT), issued at Brașov, and (3) *Foaia Poporului* (FP), issued at Sibiu. In the 19th century, Brașov and Sibiu belonged to the Austrian-Hungarian Empire (Figure 2). The dataset is published online at: https://doi.org/10.4121/uuid:2f66aeef-4227-4c5d-b239-3f6d850e1ed9 (Cheval et al., 2019).

Table 1 shows how often meteorological information used to be mentioned in the examined newspapers at the end of the 19th century. The statistics refers only to the selected collection of events (see below the description of the filtering methodology), and the relative frequency can be increased if the errors and uncertainties which kept other entries out of this study are reduced. Important differences between the three newspapers is clearly evident, likely as a result of editorial policies. Of importance, official reports issued by the meteorological service of Romania containing observations and forecasts (Annex 1) used to be published frequently in RL, which likely influenced the interest of the public for weather. However, these official meteorological reports are not utilized in this study.

The technical quality of the records is generally very good, the text is easy readable and with very few typographic error. Each available newspaper issue was thoroughly examined and the meteorological events were identified and registered in a primary database with the following structure: 1) date of the meteorological event (both in Julian and Gregorian calendar); 2) location (name of the place, SIRUTA code, county); 3) event (e.g. rainfall, extreme high temperature, snowfall, thunderstorm); 4) category (e.g. storm, hail, flood, snowpack); 5) impacts (e.g. casualties, damages); 6) source (i.e. GT, RL, FP) and date of the publication YYYYMMDD (i.e. 18890620); 7) validation (i.e. information about the event are include in the records from the nearest weather station); 8) comments. The SIRUTA code (http://colectaredate.insse.ro/senin/classifications.htm?selectedClassification=SIRUTA_S1_2018&action=general_information&classificationName=SIRUTA&classificationVersion=SIRUTA_S1_2018) was used to assign a correct and up-to-date location for each event. SIRUTA stands for *Sistemul Informatic al Registrului Unităților Teritorial – Administrative* (Informatics System of the Territorial – Administrative Units Register). SIRUTA is a classification used in Romania by the National Institute of Statistics (INS) to register Administrative-Territorial Units. Each unit has a numeric code updated every six months. The Territorial-Administrative Register is correlated with the Nomenclature of Territorial Statistics Units (NUTS) and it is structured on three levels: 1) counties and Bucharest municipality; 2) municipalities, towns, communes; and 3) localities, villages, and Bucharest sectors.

The quality control has been performed manually by double-checking all the entries, and a consistent data set has been aggregated and submitted to the validation procedure. While concerns about the credibility of the newspaper information can be always raised, validation can be approached either (1) by checking the records from the closest meteorological stations whenever available (e.g. Munro and Fowler, 2014) or (2) by inter-comparing the newspaper reports from different non-meteorological sources. In this study, the validation consisted in checking the consistency of the newspaper reports with meteorological observations from weather stations data published in *Analele Institutului Meteorologic al României* (Annals of the Romanian Meteorological Institute) (Hepites 1885–1900) and *Jahrbücher der Köningl. Ung. Central-Anstalt für Meteorologie und Erdmagnetismus* (1888, 1898, 1900, 1895).

2. Meteorological measurements and climate of Romania at the end of the 19th century

2.1. Meteorological measurements and network in Romania

This overview refers to the actual territory of Romania, but we have to mention that before 1918 the province of Transylvania was part of the Austrian-Hungarian Empire and the meteorological network was administrated accordingly. Csernus-Molnár et al. (2014) documented that the earliest long-term 18th-century daily measurement and observation series (temperature, pressure, precipitation, sky coverage, meteorological extremes) preserved in the south-eastern lowlands of the Carpathian Region at Timişoara, which is in the southwest part of Romania. Few stations with meteorological measurements in Romania were available during the mid-19th century (i.e. Lugoj starting in 1854, Sulina in 1857, and Satu Mare in 1865). In 1884 the National Meteorological Institute was founded, and 30 stations were performing meteorological monitoring systematically within the borders of Romania, while other 30 stations were in function in Transylvania (Jahrbücher der Köningl. Ung. Central-Anstalt für Meteorologie und Erdmagnetismus).

2.2. Characteristics of the temperature and precipitation

A larger perspective about the climate of 19th century epochs provides a framework on the use of some terms in the newspaper reports. In Europe, the last two decades of the 19th century were colder than the long-term average (Luterbacher et al., 2004). Bucharest, the city where RL was issued, one can notice negative temperature deviations up to 2°C along the whole period 1880–1900, while at Sibiu, the city where FP was issued, faced slightly colder-than-average years, (Figure 3A). The precipitation regime varied along the multiannual average at both stations, with no prolonged wetness deficit or surplus (Figure 3B).

3. Results and discussion

3.1. Methodological challenges

The collection of the 19th century newspaper meteorological information raised multiple issues related to temporal and spatial positioning or manipulation procedures, which were addressed in order to aggregate a consistent data set useful to obtain a relevant climatic perspective of the period. However, the results should be regarded within the objective limits imposed by several methodological challenges.

First, the date of the events and newspapers are often given either the Julian or Gregorian calendar, and the 12-day difference makes the time conversion difficult at the shift between months and years. The moment of the occurrence of a weather event can be evasive or indirect (e.g. the day before yesterday, last Friday, the Friday before Christmas), demanding dedicated attention from the investigator in order to place the event in time as correct as possible.

Second, the locations of the events are sometimes unclear, as the name may refer either to a city or to a district (e.g. Iași or Tulcea are both cities and districts), it could be completely changed in time (i.e. Piatra Neamț is the current name for Piatra) or currently having a different spelling (e.g. Bucuresci and București; Ploești and Ploiești). In cases where the location of the event was ambiguous and where the event was reported in a group of localities, we have delineated the area of the event and then identify the locality under question (i.e. identify the likely location of the event). We used geographical dictionaries, local documents and maps for tracing the toponymical history of the localities and assign the correct name and location of each event reported (i.e. *Arcanum database – Települések, Dictionary of Transylvanian localities, in Romania*). The data set described in this study includes only locations clearly mentioned in the newspapers and acknowledged today. Each location was linked to the official identifier for the Romanian localities (i.e. villages and towns) per National Institute of Statistics, namely level 3 SIRUTA code (http://colectaredate.insse.ro/senin/classifications.htm?selectedClassification=SIRUTA_S1_2018&action=structure).

Third, the weather events were extracted in the form mentioned in the newspapers (e.g. rainfall, cold day, fast snow melting), and then were grouped in several distinctive categories, resembling a content analysis approach commonly used by historical climatologists (Table 2). Complex phenomena (e.g. blizzard, thunderstorm) were split into single phenomenon (i.e. wind and snow or, respectively heavy rain and wind) in order to capture more details. The expert-based work could bias the results in this case, and the multiple-iteration was applied in order to reduce the possible errors.

3.2. Grouping the selected meteorological events in categories

The first extraction of weather reports show that a large number of terms were used at the end of the 19th century to communicate weather events and their consequences. Most of them are still in use in the current Romanian. The terminology was classified in several categories in order to simplify the understanding and avoid possible confusions between terms. For example, it is very likely that heavy and abundant rainfall, or strong wind and gusts have almost similar meaning for journalists and the general public, and one can include them in the same category. Table 2 presents the classification of the weather terms based on their common features, and the categories used for mapping and further analysis.

Other qualitative classifications refer to:

- Reference to the impact. The reports may indicate the impacts or not. They may refer to casualties or injured people, damages or environmental consequences, and they are often put in the context of various sectors or events, such as: communication and transports (i.e. railroads, wire, postal services and naval transportation); funerals, weddings, religious holidays (i.e. Easter or Christmas) other public celebrations, crops). Some reports may be fully neutral in terms of impact, mentioning only the weather event and its characteristics (Figure 4).
- Length of the reports and level of details may vary from very short and without any details, e.g. just one sentence piece of news: "*Bahluiul a debordat*" – The Bahlui river has overflown – RL 1888, March 5; or "*zăpada căzută ieri la Ploești are o grosime de 45 centimetre*" – the thickness of the snow fallen yesterday at Ploiești reached 45 cm – RL 1887, February 10, to very long and sophisticated reports (i.e. one newspaper page); usually, the weather information are presented as concise reports containing significant facts, such as phenomenon, date, place and, sometimes, consequences.
- Style and language. Most reports were aligned to the journalistic writing and style, striving for brevity and objectivity. However, the reader can find more epithets, metaphors and figures of speech than in the present news feed (Figure 5).

3.3. Frequency of newspaper reports of different weather categories

Mass media attempts to bring describe the most impactful and spectacular events to the public as fast as possible, and the meteorological phenomena have been always a favourite topic for prime time and breaking news. The frequency of the weather and weather-related events in the selected newspapers illustrates the interest of the public, but also returns a glimpse over the climate of the epoch and the interest of the public. Apparently, at the end of the 19th century, rainfall, storm and hail were the most powerful attention-getting phenomena, with about 70% of all weather reports identified in the selected newspapers

(Figure 6). Flood, thunderstorm and blizzard phenomena (i.e. the 3rd, 4th and 5th in terms of frequency) are also related with significant precipitation, while temperature hazards have considerably lower occurrence.

3.4. Seasonal frequency of the weather reports in the selected publications

The intensity and frequency of convective events with direct and immediate impact on society (e.g., tornadoes, hail, and flash floods) can generate more interest from mass media than regular weather events. As a consequence, the frequency of weather reports in the selected newspapers follow a clear seasonal pattern, with a maximum during the warm months (May–September, representing the convective season in Romania), summing up about 82% of the total number of all events (i.e. 2132 events) (Figure 7). One event may be reported in more than one locality.

3.5. Geographical distribution of the phenomena from weather reports in the selected publications

Most weather reports have clear indications of the geographical position, making possible to draw the spatial distribution of the phenomena. Figure 8 includes all the weather events reported and show the focus of each newspaper on distinct territories, considering their head offices and the interest of the readers. RL focused on the eastern and southern regions containing the historical provinces Muntenia, Dobrogea and Moldova (i.e. the Kingdom of Romania), and GT and FP used to report mainly events from central and western Romania, namely Transylvania (i.e. part of the Austrian-Hungarian empire, at that time). One can notice the very good overall geographical coverage of the reports. More details about the locations of each weather category are available in Annex 2. The reports on weather events are well balanced over the territory, and the high frequency of certain phenomena, such as flood, hail or rainfall (Figure 9), is noticeable in their spatial distribution.

3.6. Comparison between weather information retrieved from newspaper reports and meteorological station data

Based on the results of the comparison between each newspaper report and meteorological records from the closest stations, three levels of validation were identified: (1) confirmed entries, for a match between newspaper and data from weather stations within 20 km-distance, at ±1 day lag; (2) partially confirmed entries, for match between newspaper and data from weather stations within 20 km-distance, at ±2 to 5-day lag, and (3) not confirmed entries, either because meteorological data are missing or they do not match with the newspaper event. The validation refers to a random sample of only 506 entries, from the total number of entries, and 142 entries (28.06%) of them were confirmed and partially confirmed. Taken into account the strictness of criteria, the context and the type of the information to be compared (i.e. many visual approximations and subjective information versus instrumental measurements in standard conditions), one can state that we obtained a very good rate of validation.

4. Conclusions

This is the first study examining the potential of newspapers issued at the end of the 19th century to enhance the climate outlook in Romania and in South-Eastern Europe. It demonstrates that newspaper collections may disclose abundant meteorological evidence to support climate reconstruction and extreme weather events down to the sub-daily timescale, especially for the pre-instrumental period and for areas with sparse networks.

In the three selected newspapers, the frequency of newspaper issues containing useful meteorological information may exceed 20%, but the variations from one newspaper to another can be high. The weather reports focus on high impact phenomena, such as rainfall, storm and hail, but we identified 19 categories of weather events present in the newspapers. The spatial distribution of the reported phenomena covers the entire territory of Romania, while the temporal regime emphasizes a higher occurrence of weather reports during the warm season.

Due to inherent uncertainties associated with such information and considerable efforts needed for obtaining valuable data, these newspaper reports have been underexploited by climate experts. There are several shortcomings which should be recognised, such as: (a) missing or incomplete information due to lack of newspaper issues in some days; (b) insufficient accuracy of information in terms of date, location and characteristics of the event (e.g. intensity, type or areal extension are not enough clear); (c) misinterpretation of the storyline due to language, low quality of the publication output; (d) difficulties to compare the outputs of newspaper collections unequal in terms of frequency, geographic coverage, or editorial policies.

Nevertheless, important benefits can be claimed for the use of newspaper information as proxy-source for climatic reconstruction if thorough analysis of the data is performed, including quality checks, filtering and validation. This investigation has provided useful indications about assessing the climate of Romania at the end of the 19th century extracted from only three publications, while newspapers issued in the South-Eastern Europe in the epoch are still waiting to be explored from this perspective.

Further research will be pursued based on the findings of this paper through case studies and integration of other types of documentary data (e.g., diaries and early instrumental records), and natural paleoclimate proxies. In-depth research of each phenomenon and comparison with neighbouring areas are also expected to enhance the knowledge about the climate of the 19th century in the central and SE Europe.

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List of figures and tables

Figure 1 Romania's location in Europe (The location of the study area (Romania) in Europe)

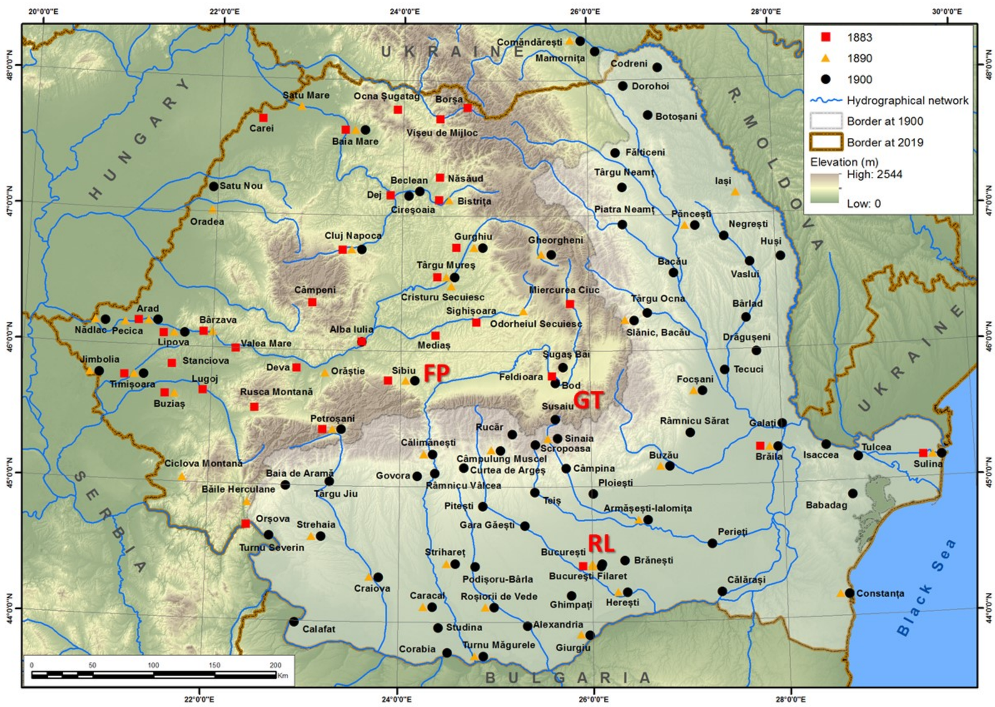


Figure 2 Meteorological stations in Romania in 1900 (black dots) and the location of the examined newspapers România Liberă (RL), Gazeta de Transilvania (GT), and Foaia Poporului (FP).

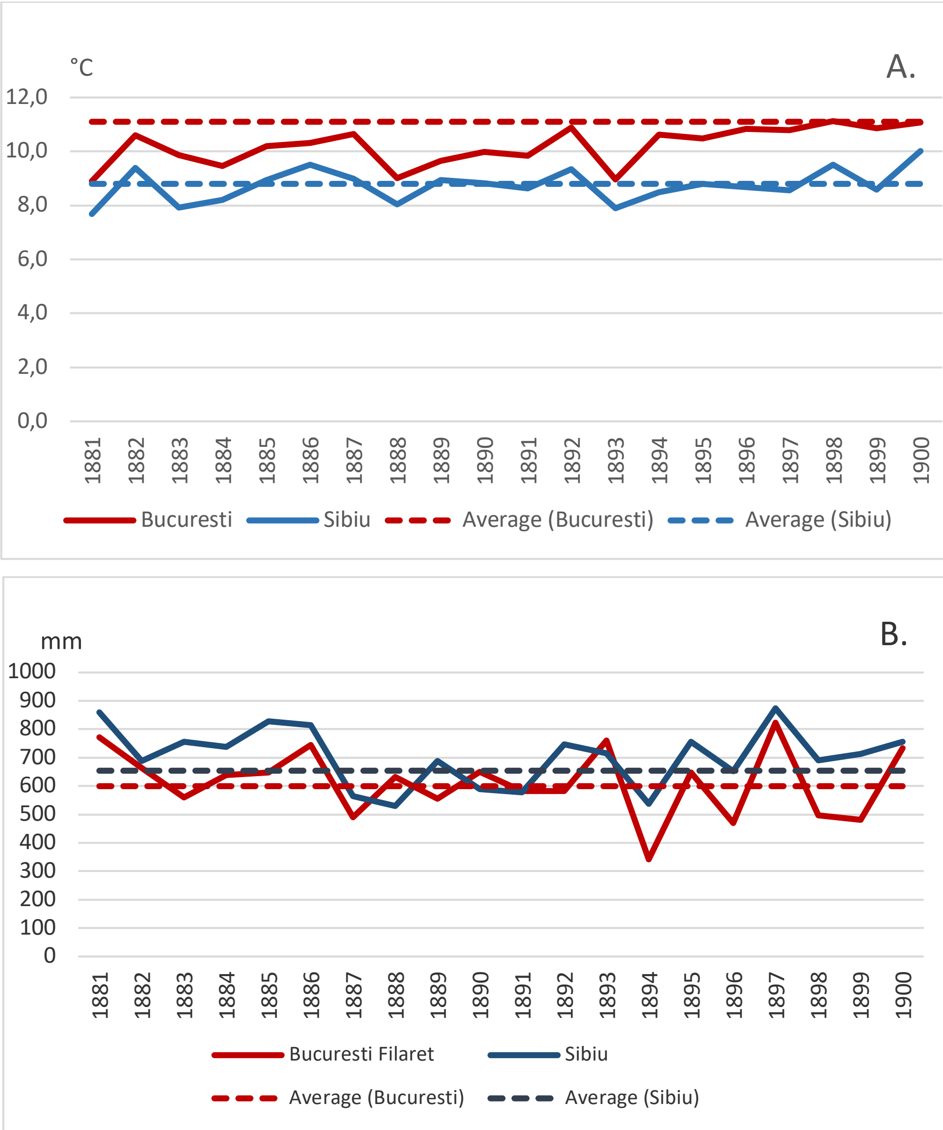
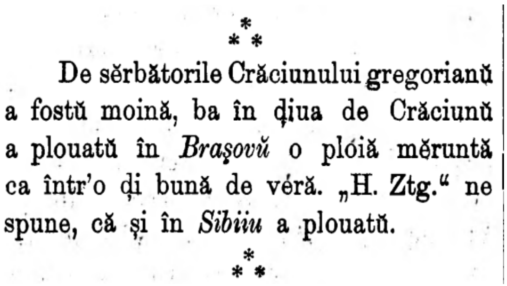


Figure 3(A) The average annual temperature and **(B)** precipitation at Bucharest (red line) and Sibiu (blue line) between 1881–1900 versus long-term annual average (1881–2015) (dashed lines).



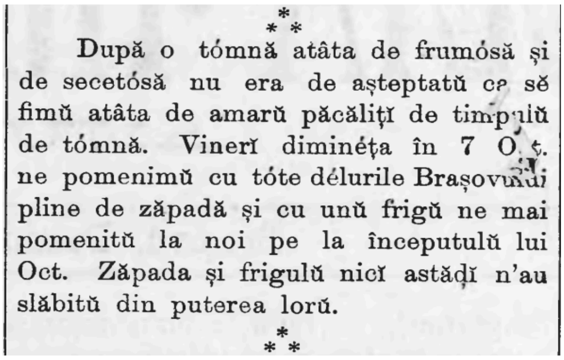
*
* *

De sĕrbătorile Crăciunului gregorianŭ a fostŭ moină, ba în ḑiua de Crăciunŭ a plouatŭ în *Braşovŭ* o plóiă mĕruntă ca într'o ḑi bună de véră. „H. Ztg.“ ne spune, că şi în *Sibiiu* a plouatŭ.

*
* *

During the Christmas holiday it started to thaw, and in Brasov the Christmas day was rainy, with summer-like drizzle. The newspaper H. ZTG reported rain also in Sibiu.

Figure 4 Weather report from Braşov and Sibiu describing “summer rain” falling during Christmas (Gazeta de Transilvania, Saturday 17 (29) December 1888)



***
După o tómnă atâta de frumósă și de secetósă nu era de așteptatŭ ce sĕ fimŭ atâta de amarŭ păcăliţĭ de timpuluĭ de tómnă. Vinerĭ diminéţa în 7 Oct. ne pomenimŭ cu tóte délurile Brașovuluĭ pline de zăpadă și cu unŭ frigŭ ne mai pomenitŭ la noi pe la începutulŭ lui Oct. Zăpada și frigulŭ nicĭ astădĭ n'au slăbitŭ din puterea lorŭ.
***

After a warm and dry fall, one could not expect surprises. However, Friday at 7 in the morning, we found snow on all the hills around Brașov, and the bitter cold spell unusual at the beginning of October is still persistent today.

Figure 5 Weather report from Brașov city describing an unexpected snow and cold event in early October following warm and dry autumn weather (Gazeta de Transilvania, Sunday 9 (21) October 1888)

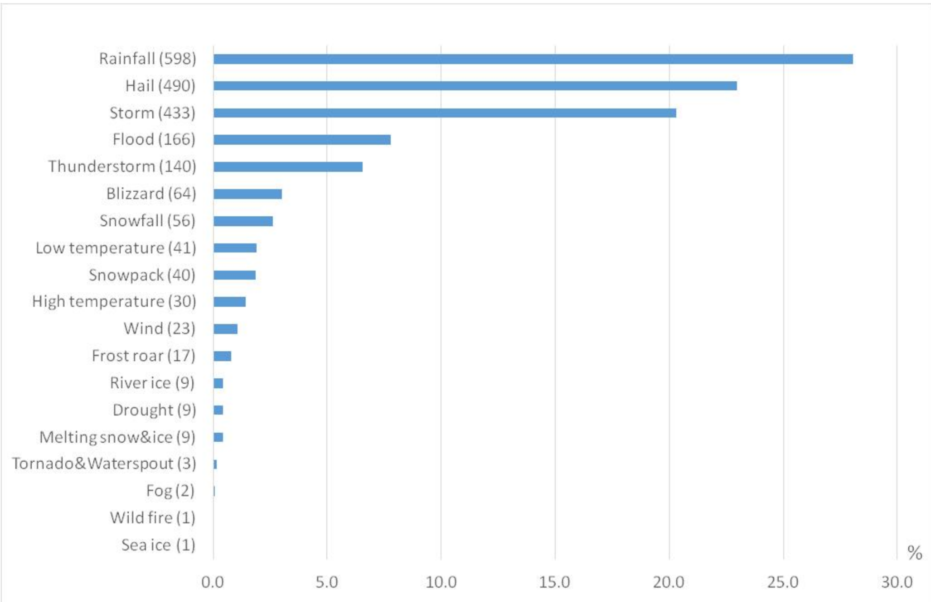


Figure 6 Absolute number (in the brackets) and relative frequency of weather and weather-related events in GT, RL and FP reports (1879–1900).

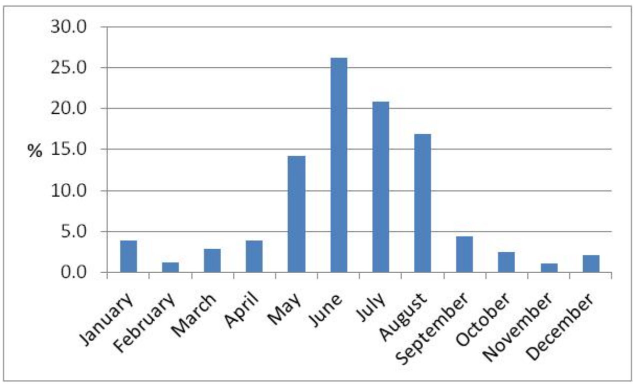


Figure 7 Monthly frequency (%) of all the weather events mentioned in GT, RL and FP reports (1879-1900)

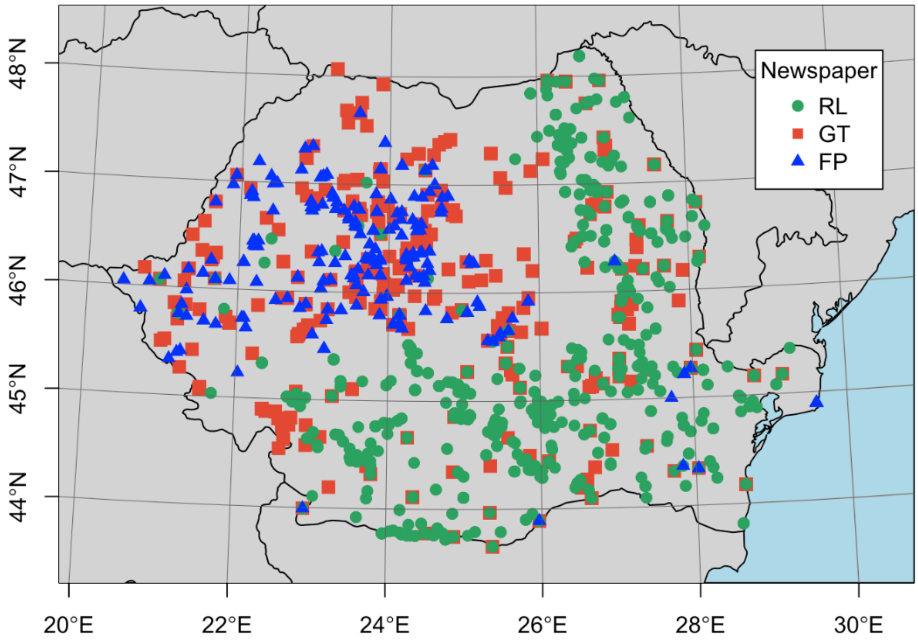


Figure 8 Spatial distribution of all-weather events mentioned in GT, RL and FP reports (1879–1900)

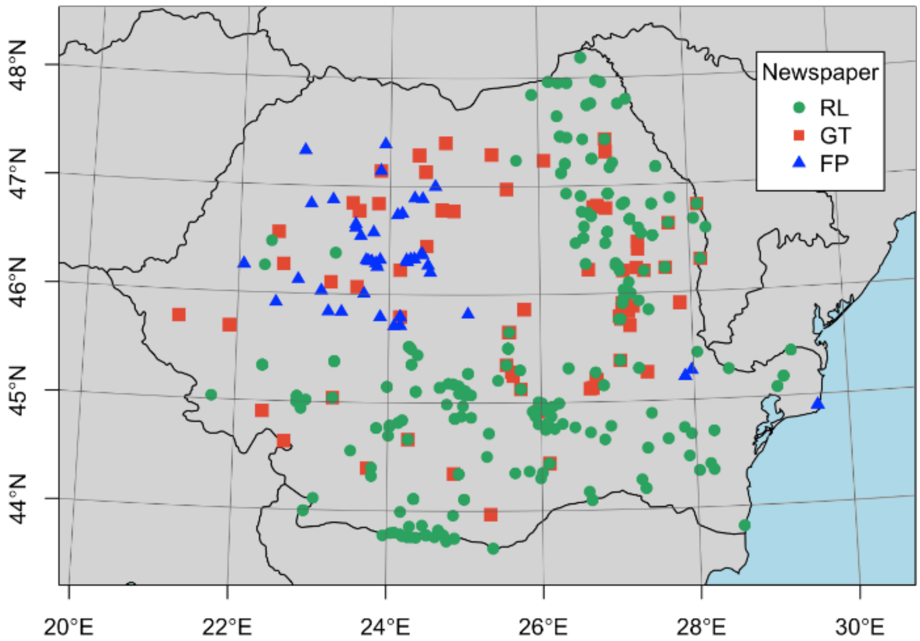


Figure 9 Spatial distribution of the rainfall events mentioned in GT, RL and FP reports (1879–1900)

Table 1 Absolute and relative frequency of newspaper issues containing meteorological information from total number of newspaper issues. Number of weather events selected for this study

Newspaper, abbreviation and source website	Examined period	Total issues per newspaper	Issues containing meteorological information from the total number of newspaper issues	Number of unique entries (1 entry = 1 weather event / locality)
România Liberă (RL) http://www.digibuc.ro/	January 1885 – June 1889	1004	221 / 22.0%	1454
Gazeta de Transilvania (GT) http://dspace.bcucluj.ro/	January 1879 December 1900	5005	336 / 6.71%	796
Foaia Poporului (FP) http://dspace.bcucluj.ro/	January 1893 – December 1900	389	78 / 20.1%	271
TOTAL	-	6398	635 / 10.0%	2521

Table 2 List of weather events identified in the newspapers of the 19th century grouped by categories.

Meteorological events		Category
Romanian terminology	**English terminology**	
Vreme caldă, căldură, temperaturi mari, caniculă, căldură tropical	Warm weather, hot, high temperature, heat, tropical warm	High temperature
Vreme rece, timp rece, frig, temperaturi mici, ger	Cold weather, coldness, low temperature, frost	Low temperature
Ploaie, timp ploios, Ploaie torențială / abundentă / intense	Rainfall, heavy / abundant / intense rainfall	Rainfall
Orcan, uragan, ciclon, furtună, vijelie	Hurricane, (heavy) storm, cyclone	Storm
Tunet	Thunder	
Fulger, trăznet, descărcări electrice	Lightning	Thunderstorm
Furtună cu trăznet, furtună cu tunet, vijelie	Thunderstorm	
Inundații, ape mari, viituri, vărsare de apă	Flood, flash flood	Flood
Secetă, uscăciune	Drought, dryness	Drought
Vânt, vânt puternic, vijelie, vânt violent	Wind, wind gusts	Wind
Tornadă, tromba	Tornado, waterspout	Tornado
Ninsoare	Snowfall	Snowfall
Zăpadă	Snowpack	Snowpack
Viscol	Blizzard	Blizzard
Grindină	Hail	Hail

Brumă	Frost roar	Frost roar
Sloiuri de gheață	River ice	River ice*
Marea înghețată	Sea ice	Sea ice
Topirea zăpezii, topirea gheții	Melting snow, melting ice	Melting snow
Ceață	Fog	Fog
Foc de vegetație	Wild fire	Wild fire

*A distinct category is dedicated to the ice on Danube, namely Danube ice