Quaternary International 415 (2016) 109–125

Contents lists available at ScienceDirect

Quaternary International

journal homepage: www.elsevier.com/locate/quaint

Natural proxy records of temperature- and hydroclimate variability with annual resolution from the Northern Balkan–Carpathian region for the past millennium – Review & recalibration

Zoltán Kern [a], Alexandra Németh [a], Margit Horoszné Gulyás [b], Ionel Popa [c], Tom Levanič [d], István Gábor Hatvani [a, *]

[a] Institute for Geological and Geochemical Research, MTA Research Centre for Astronomy and Earth Sciences, Budaörsi út 45, H-1112 Budapest, Hungary
[b] Óbuda University, Alba Regia Technical Faculty, Institute of Geoinformatics, Pirosalma utca 1-3, H-8000 Székesfehérvár, Hungary
[c] National Research and Development Institute for Silviculture Marin Dracea, Calea Bucovinei 73 bis, 725100 Cimpulung Moldovenesc, Romania
[d] Slovenian Forestry Institute, Vecna pot 2, SI-1000 Ljubljana, Slovenia

ARTICLE INFO

Article history:
Available online 2 June 2016

Keywords:
Climate proxy
Moisture & temperature records
Spectral signal enhancement spring
Summer
Winter

ABSTRACT

A systematic compilation of temperature (n = 10) and moisture sensitive (n = 4) proxy records of the Northern Balkan–Carpathian (NBC) region with annual resolution for the past millennium is presented and evaluated. The proxy-climate relationship is re-evaluated using a uniform climatological dataset providing a longer calibration. The originally determined response seasons were in the most part verified. Spectral constraints were established by combining wavelet coherence analysis and band filtering, thus, the signal-to-noise ratio was successfully improved in certain cases, either by separating the temperature/moisture sensitive frequencies in complex signals, and/or by extracting "focus" bands. In the case of winter temperature, the earliest available dates in the natural proxy records were 1774 AD, for spring and summer they were 1732 AD and 1040 AD respectively, while for hydroclimate this date was 1497 AD. Although only one record was available for winter, it showed a pronounced similarity to winter temperature reconstructions from adjacent areas outside the NBC. Spring thermal proxies were comprised of grape-vine phenology data from the Western NBC margin, these being in quite good agreement with each other, for instance, in the case of the characteristic mutual decadal pattern the mild springs of the 1750s. In addition, a common long-term cooling trend was observed, starting in the mid-18th century and ending at the turn of the 20th century. The comparison of summer temperature records indicated that proxies of the same origin/source tend to show a stronger mutual variation than those located close to each other, but of different types. This serves as a warning in the interpretation of climate field reconstructions from multiproxy networks.

The studied summer proxies show a remarkably strong linear relationship with nearby records outside the NBC, weakening as their distance increases. The two most persistent multi-decadal cold summer periods (~1780–1840 & 1430–1500 AD) were decisively mirrored in the proxies. The longest and most recent reconstruction from the North Slovakian Tatras shows a unique warming (after ~1900 AD) reflected neither within, nor outside the NBC, casting doubt on its reliability. In general, weaker coherence was observed between the hydroclimate proxies, drawing attention to a general phenomenon: the range of the spatial representativity of hydroclimate proxies is usually smaller. Therefore, their network should be further developed. One of a few shared regional summer drought periods occurred in the 1750s, being most pronounced in the Central and Southeastern NBC. Moreover, this was reflected in the neighboring South Moravian drought history, too. These results will hopefully serve as a stepping-stone for future research on spatiotemporal patterns of climate changes and their causes in the NBC region.

* Corresponding author.
E-mail addresses: kern@geochem.hu (Z. Kern), nemethalexandra89@gmail.com (A. Németh), horoszne.margit@amk.uni-obuda.hu (M. Horoszné Gulyás), popaicas@gmail.com (I. Popa), tom.levanic@gozdis.SI (T. Levanič), hatvaniig@gmail.com (I.G. Hatvani).

http://dx.doi.org/10.1016/j.quaint.2016.01.012
1040-6182/

1. Introduction

In climate research, the regional approach to climate variability and change is becoming an increasingly important topic. An accurate understanding of the past one or two thousand years of Earth's climate history is critical in placing recent changes in the context of natural climate variability (PAGES 2k Consortium, 2013).

The need for a better understanding of these phenomena is driven by the fact that local and regional climate variability (amplitudes and rates) (i) is much higher than variability on the global scale, and (ii) affects natural/managed environments and ecosystems services rather than global climate variability.

Besides large-scale climate reconstruction efforts focused on the last one to two thousand years (Moberg et al., 2005; Ljungqvist, 2010; Christiansen and Ljungqvist, 2012; PAGES 2k Consortium, 2013), regional multiproxy compilations have also been prepared (Neukom et al., 2009; Klimenko and Solomina, 2010; Przybylak et al., 2010; Neukom et al., 2011; Trachsel et al., 2012; Tingley and Huybers, 2013; Trouet et al., 2013; Klimenko et al., 2014; McKay and Kaufman, 2014; Shi et al., 2015). Although Europe, on a global scale, has the greatest wealth of high-quality information for paleoclimate variability, the Northern Balkan–Carpathian (NBC) area is a region relatively poor in data in comparison to the rest of the continent. By gathering related studies of non-documentary climate evidence, the contours of a new database could be outlined, filling the niche in paleoclimate research of the NBC.

On an international level this work corresponds to the goals of the PAGES 2k initiative (Newman et al., 2009; Kaufman, 2014) in that it provides for the first time an improved and quality-checked long, high-resolution, sub-continental, temperature and hydroclimate proxy data collection for the studied region. This data can thus serve as a benchmark by which to measure the ability of regional climate models to reproduce past variability (Renssen and Osborn, 2003) and thereby evaluate the degree of uncertainty in future predictions. As an initial step, 10 temperature- and 4 moisture sensitive proxy reconstructions published for the NBC region during the past decade were assessed with the following aims:

(i) to provide a comprehensive literature collection of temperature- and moisture sensitive natural proxy records covering a significant part of the past 1000 years, with annual resolution guaranteed.
(ii) to recalibrate these records using the longest uniformly available climatological target variable at each site and proxy, and compare the results with the original calibrations.

In addition, an earlier European-scale climate field reconstruction (CFR) for the past 500 years covering all or part of the NBC area (Luterbacher et al., 2004; Pauling et al., 2006) included a single documentary derived historical climatological index series (Rácz, 1999) integrating documentary evidence for a very large area. Hence, representing the whole NBC region solely with this 'bulk' series may render it impossible for us to see the potential sub-regional differences. Furthermore, the reconstructions are biased towards the regional mean climate, as illustrated for instance, by the comparison-maps of a very recent European drought reconstruction (Cook et al., 2015). Besides the updated dataset, an exigent selection criterion, the re-evaluation/re-calibration attempt, and the special attention paid to the potential proxy-specific and sub-regional differences make this work different from previous review papers, e.g. Bartholy et al. (2004) and Vadas and Rácz (2010, 2013). It should be noted here that the derivation of any new numerical reconstruction or CFR is still beyond the scope of the study, mostly because the currently available proxy network is very sparse.

Nevertheless, the major goals of the study are (i) to obtain a comprehensive picture of the proxies already at hand from the NBC before utilizing them in large scale CFRs, (ii) to evaluate the potential (dis)agreement of the climate histories represented by the proxy records in different parts of the NBC, and (iii) to indicate the most critical areas where there is a strong need to develop new reliable proxy data.

2. Materials and methods

The climate of most of the NBC can be categorized as continental with warm summers (Köppen code: Cfb). The continentality increases eastwards, while Mediterranean characteristics appear in the southern/southwestern sector. A boreal climate with warm summers (Dfb) prevails over the larger part of the Carpathian mountain belt and its cool summer variant (Dfc) characterizes smaller parts of the northern and eastern ranges (Fig. 1; Kottek et al., 2006), while a tundra climate (Köppen code: ET) is also found, though restricted to the regions of the highest peaks.

The frost period ($T_{month} < 0\,^{\circ}C$) is in general one to three months long. It would appear that the SE areas are the only ones where the average temperatures do not, or only slightly fall below zero (Fig. 1G).

The rainiest period is May–June over most of the studied region (Fig. 1A–F), while a slightly earlier rainfall peak is observed the SE sector (Fig. 1G, H). A second, minor, rainfall peak occurs around November.

Arid conditions usually prevail in late summer over the lowlands (Fig. 1B, G), especially where hot summers (Cfa) are accompanied by a relatively lower total precipitation.

2.1. Proxy dataset acquired

In every case, the chosen records had to meet the following criteria:

(i) they had to be from the region encompassed by 44.5–50°N and 15–26.5°E;
(ii) evidence had to be present that the record is sensitive to a climate parameter. This evidence may be statistical (e.g., correlation with a nearby instrumental record), or mechanistic (e.g., description by the authors of mechanisms by which the archive senses temperature change);
(iii) they had to reach back in time to before the beginning of continuous instrumental meteorological observations in the region, as benchmarked by 1775 AD for temperature (Vienna) and 1841 AD for precipitation (Budapest and Vienna); and
(iv) they had to have an annual resolution.

Original proxy data were acquired from public data repositories or from the authors of the original studies. For the detailed basic information see Table 1 and Fig. 1, while a brief description of each kind of proxy data, with special emphasis on the climate sensitivity (parameter and season) is provided in the Supplementary Content.