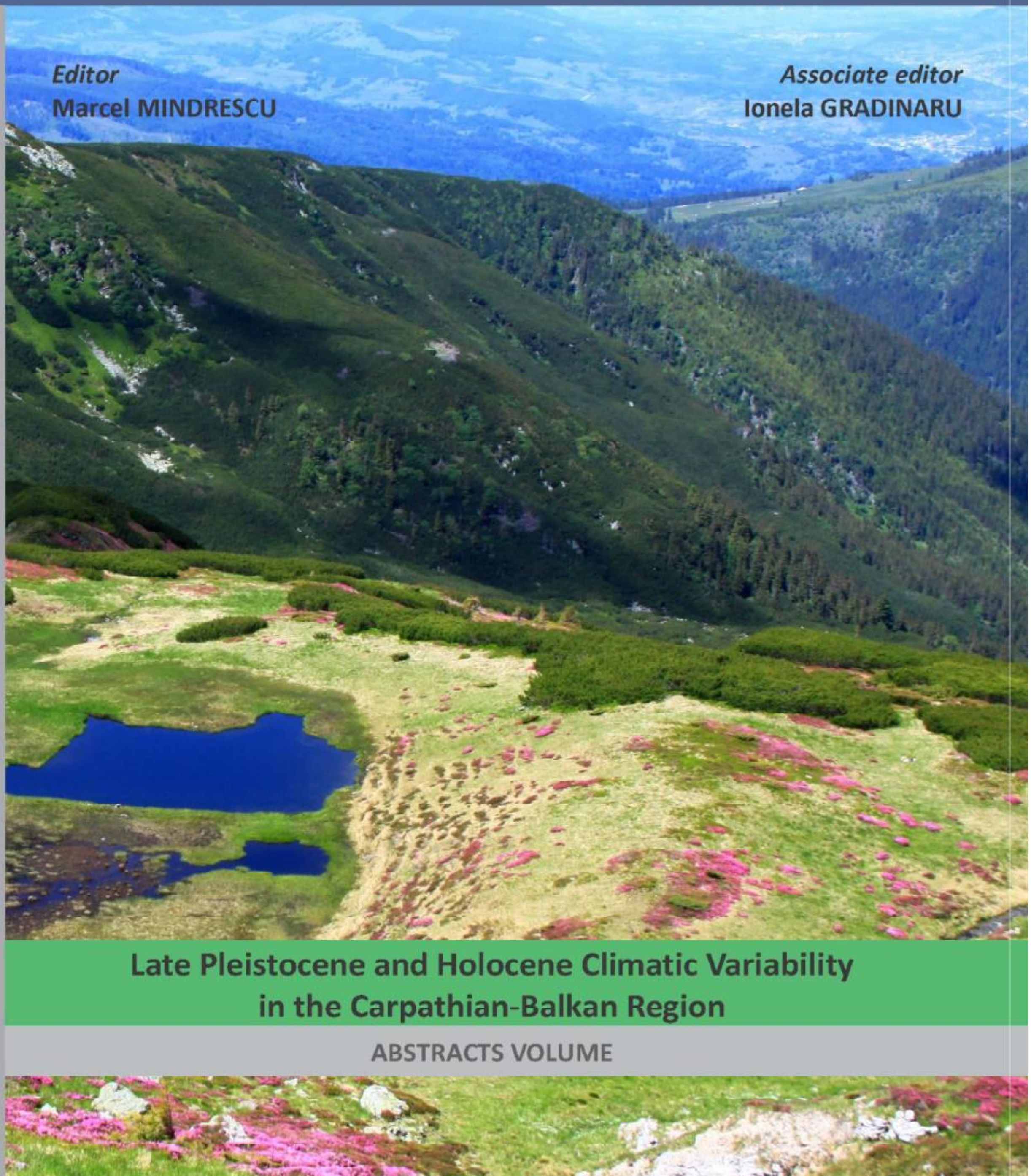
PAGES
PAST GLOBAL CHANGES

cirques & lakes
PN-II-RU-TE-2012-3-0386

Editor
Marcel MINDRESCU

Associate editor
Ionela GRADINARU



Late Pleistocene and Holocene Climatic Variability in the Carpathian-Balkan Region

ABSTRACTS VOLUME

Ştefan cel Mare University Press

Nov. 2014
Late Pleistocene and Holocene climatic variability in the Carpathian-Balkan region. Abstracts volume
Ştefan cel Mare University Press

Dendroclimatic Reconstruction of Summer Temperatures in Irik Valley, Mount Elbrus (Greater Caucasus)

Iulian Horia Holobâcă, Olimpiu Pop and Danut Petrea
Babes-Bolyai University, Faculty of Geography, Cluj-Napoca, Romania, holobaca@geografie.ubbcluj.ro

Recent evidence suggests an acceleration of glacier retreat in Greater Caucasus after 1980. For the same period a significant summer temperature warming trend and little or no change in precipitation variation have been observed. In this paper we seek to find similar past climatic conditions using a dendroclimatic reconstruction of summer temperatures from upper treeline sites after the Little Ice Age (LIA). Dendroclimatological sampling of Scots pine (Pinus sylvestris) has been made in Irik Valley, near Elbrus glacier, and a tree-ring width (TRW) chronology has been used to reconstruct May – August (MJJA) temperatures back to 1830. Three warm periods were identified in the MJJA temperatures reconstructed data (1830 - 1900), but we cannot appreciate if they had the same intensity as the recent warm period.

Keywords: climate variability, ablation, dendrochronology, Elbrus glacier

Introduction

Former studies have shown an important increase in the temperature (0.5 ^{o}C / decade) and no significant change in precipitation in the high altitude areas of the Caucasus after 1980 (Shahgedanova et al., 2005, Holobaca, 2013). Glaciers are retreating in the Caucasus in response to the observed climatic warming. Over 90% of the glaciers retreated between 1985 and 2000, while the total glaciated area decreased by 10% (Stokes et al., 2006).

The instrumental climatic data and remote sensing data cover mainly the 20th century, and more than 100 year-old weather stations are rather far from the studied area, therefore proxy methods (e.g. dendrochronology, sediment analysis, ice-core, pollen analysis, etc.) are suitable to reconstruct the long-term climate variability.

Despite a high dendrochronologic potential, there is one notable spatial gap in the regional coverage of dendroclimatic reconstructions in the Caucasus Mountain, where only limited dendroclimatological research has been completed. The first quantitative reconstruction of air temperature for the warm period in the Caucasus based on dendrochronological data has been carried out only in 2010 (Dolgova and Solomina, 2010).

Methods and data

Study area

The studied area is located in the North Caucasus Mountains in the Russian Federation around Elbrus (5624 m), the highest peak in Europe, Russia, and the Caucasus.

Elbrus has a continental temperate climate with high precipitation in summer and cold winters. A total area of 111 square km (in 2007) of Elbrus is covered by ice. The Mount Elbrus is covered with a well-developed ice cap which descends down to 3500 m a.s.l. From this ice cap, glacier tongues are radiating from a common firn basin. These valley glaciers descend down to 2300 m and feed the Kuban River and some of the headwaters of the Terek.

Dendroclimatic reconstruction of the climate variability

Our tree sampling area is situated in the upper tree line on the Irik Valley, about 2300 m. In agreement with dendrochronological principles, 30 Scots Pines (*Pinus Sylvestris*) have been selected for sampling following classical techniques used in dendroclimatology. The 60 increment cores have been prepared for analysis (fixed in a wood support, dried and sanded) and then the tree-rings were measured with 0.001 mm precision using a LINTAB 5 station (a positioning table connected to a Leica stereomicroscope and TSAP-Win Professional software) (Rinntech 2005).

Quality control and data check of the tree-ring measurements have been performed using COFECHA (Holmes, 1983) software by transformation of time series. Each transformed series has then been tested against the dating master series, segment by segment. Successive segments have been lagged with a 50% overlap.

The tree-ring standardization and removing growth trends in ring-width data has been carried out using ARSTAN software (Cook and Krusic, 2007). The chronology series has been calculated using a bi-weight robust mean. Residual chronological series (RES) have been used in this study.

Several standardization methods (Regional Curve Standardization (RCS), General Negative Exponential Curve (GNEC), Spline 32 years with 50 % of variance cutoff, Hugersoff growth curve) have been tested. The best correlation coefficients for the tree-ring growth index against the climatic data have been observed for the Hugersoff growth curve method.

The connection between climatic time series and the seasonal ring structure indices has been carried out using DendroClim. The transfer function employed for May-August (MJJA) temperature reconstruction has been estimated using a general linear model (GLM).

Results

Dendroclimatological analyses

a) Response of the climatic factors on the tree-rings growth. The dendrochronological series for Scots Pine from the Irik area has a length of 209 years, between 1800 and 2009, but Expressed Population Signal (ESP) is above the 0.85 threshold after 1830. The reconstructed summer temperatures are reliable only after this date. In the Scots Pine chronologies studied, the average sensitivity of the individual series varied between 0.134 and 0.252. The overall average is 0.176 and it indicates a medium response to the variation of the climatic factors. This medium response is indicated by other two dendrochronological indicators: average correlation between the individual series (rbar) is 0.561 and the variability explained by the first principal component (PC1) for commune, climatic data and tree-ring growth index period, is about 32 %.

b) The response of the climatic factors on the tree-rings growth in current and previous vegetation seasons. Our analysis is based on the mean monthly temperature and on the monthly amount of precipitation starting from April of the year before the growing of the current ring (t-1) to October of the year of the present ring growing (t). The correlation coefficients between these time series and current growth index were computed. The statistical significance was tested using t-test for a significance level of 95%.

The July and August (JA) temperatures of the current year and May and June (MJ) temperatures of the previous year have a significant correlation with the ring growth. A positive, significant correlation is observed for March temperatures for the current growing season. No significant correlation with precipitation has been noticed. The results show the positive effect of temperature on growth in early summer of the previous growth season and summer of the actual growth season. In this cold and wet mountain climate, the summer temperature is the principal limitative factor on tree growth near the upper tree line (here at about 2400 m a.s.l.).

b) The dendroclimatic summer temperature reconstruction results. In order to better use the climatic information suggested by the response function, we have made two temperature reconstructions back to 1830, one for July-August for the actual growth season and another for May-June for the previous growth season. Using a general linear model, the transfer function was quantified as follows:

$$\mathbf{T_{MJ}} = \mathbf{I_{i+1}}*2.219+3.741 \text{ with } R = 0.298 \text{ for MJ} \quad (4)$$

and

$$\mathbf{T_{JA}} = 1.619* \mathbf{I_i} + 9.269 \text{ with } R = 0.230 \text{ for JA.} \quad (5)$$

where: - T_{JA}- July to August mean temperature;

- I_i - tree-ring growth index value at the moment i.;
- R - Pearson correlation coefficient;

The warm season temperatures (MJJA) have been reconstructed using the t value from the MJ reconstructed temperature and the t -1 value from the JA temperatures. The correlation coefficient between the observed values and the ones estimated by the model, for the validation period, is 0.37, statistically significant at the 5 % level.

Because of the standardization method used and the length of dendrochronological data, the low-frequency variability has been removed. The proposed chronologies preserve relatively well the high and medium-frequency variability.

Our study highlights the medium-frequencies variability in order to identify the warm periods with impact on the mass balance of the Elbrus glacier. The decadal variability in MJJA reconstructed and observed temperatures have been analyzed applying a spline 20 years with 50 % of variance cutoff function.

In this decadal variation, one can identify the same climatic signal, but the reconstructed data have diminished amplitude and the signal is delayed. The lower amplitude may be explained by the standardization of ring-width data and the delay by the late biological response of the trees to temperature changes.

Based on the analyses of the two temporal series, we emphasize alternative sequences decades with warm/cold summers. In the observed data, the intervals 1908-1922, 1939-149, and 1959-1995 had cold summers, while summer experienced warm temperatures during the periods

1923-1938, 1950-1958, and 1995-2009. The reference was the World Meteorological Organization (WMO), which recommended 1960-1990 temperature normal, derived from observed data. We also have found 3 warm periods in our reconstructed data: the first one occurred after 1830, the second one after 1860, and the third at the end of the 19th century and the beginning of the 20th century. The last one is validated by observed data.

Discussion

The dendroclimatological analysis produced only limited results. The inherent incertitude of this method and relatively low correlation between tree-ring growth and climate parameters for our tree-ring chronology, make the comparison between the reconstructed warm periods and the recent one very difficult.

Three warm periods have been observed in our reconstructed data, but we cannot appreciate the intensity of warming or their exact length. Further dendroclimatic temperature variability reconstruction, combined with others proxy methods could have an important potential for glacial dynamics understanding in the studied area

Conclusions

The dendroclimatological analyses of summer temperatures in the Irik Valley allow us to reconstruct the historical variation of temperatures in the main ablation period (MJJA) back to 1830. We found warm periods in the past variations of temperature but we cannot conclude regarding their intensity.

References

Cook, E.R., Krusic, P.J., 2007. ARSTAN – a Tree-Ring Standardization Program Based on Detrending and Autoregressive Time Series Modeling, with Interactive Graphics. Tree-Ring Laboratory, Lamont Doherty Earth Observatory of Columbia University, Palisades, NY.

Dolgova E.A., O.N. Solomina, 2010, First quantitative reconstruction of air temperature for the warm period in the Caucasus based on dendrochronological data. Doklady Academii Nauk, 43(1):371-375

Holobaca I.H., 2013, Glacier Mapper – a new method designed to assess change in mountain glaciers, International Journal of Remote Sensing 09/2013; 24(23):8475-8490.

Shahgedanova, M., C. R. Stokes, S. D. Gurney, and V. Popovnin. 2005. "Interactions Between Mass Balance, Atmospheric Circulation, and Recent Climate Change on the Djankuat Glacier, Caucasus Mountains, Russia." Journal of Geophysical Research-Atmospheres 110: 49–64.

Stokes, C. R., S. D. Gurney, M. Shahgedanova, and V. Popovnin. 2006. "Late-20th-Century Changes in Glacier Extent in the Caucasus Mountains, Russia/Georgia." Journal of Glaciology 52 (176): 475 99–109.