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Climate response to de Vries solar cycles: evidence of Juniperus turkestanica tree rings in Central Asia

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Abstract. A manifestation of the two-hundred-year solar cycle (de Vries cyclicity) in climatic changes is considered. The consideration is based on analysis of radial growth of long-lived (800-1200 years) trees *Juniperus turkestanica* from Tien Shan mountains (Central Asia). Quasi-two-hundred-year oscillations in radial tree growth which correlate well (correlation coefficient is 0.82) with similar solar activity variations (Δ^{14}C) and the 200-year component of temperature variations in the Northern Hemisphere in the last millenium and also with quasi-two-hundred-year variations in climatic processes in Europe, North and South America, and Asia have been revealed. The results obtained point to the influence of the deVries solar activity periodicity on global climatic processes.

Key words. Climate change – long-term solar activity – de Vries cyclicity

1. Introduction

It is commonly believed at present that the ~200-year solar cycle (deVries cycle) is one of the most intense solar cycles. This is evidenced, for instance, by occurrence of deep solar activity minima (Maunder, Spörer, Wolf) in approximately two-hundred-year intervals during the last millennium. By using the proxy data on solar activity variations (^{10}Be concentration in Greenland ice), Wagner et al. (2001) traced the development of the de Vries cyclicity for the period 50,000 - 25,000 years BP. Vasil'ev et al. (1999) inferred from the data on variations in ^{14}C in tree rings that the ~200-year solar cycle is one of dominating solar cycles during the Holocene. The time coincidence between the development of Maunder, Spörer, and Wolf minima and expansion of Alpine glaciers Haeberli & Holzhauser (2003) point to a climatic response to the deep solar minima. A similar conclusion was inferred from analysis of glacier expansion in Alaska Wiles et al. (2004).

The goal of this paper is to reveal the ~200-year climatic cycle in Central Asia by analyzing the tree-ring growth data for *Juniperus turkestanica* at the high timberline in Tien Shan mountains and to compare the obtained palaeoclimatic data with the development of

Send offprint requests to: O. Raspopov the de Vries periodicity during the last millennium.

2. Data, methods, results

To reveal long-term climatic changes during the last millennium, variations in tree-ring widths of *Juniperus turkestanica* (ΔR) growing in Central Asia in Tien Shan mountains at altitudes higher than 2800-2900 meters whose age can reach 2,000 years Mukhamedshin & Sarbaev (1988) were used as a palaeoclimatic parameter. It follows from the analysis of the effect of temperatures and precipitation on the radial growth of *Juniperus turkestanica* carried out by Mukhamedshin & Sarbaev (1988) that in mountains the radial growth of *Juniperus turkestanica* is governed by the June-July temperature regime and is nearly independent of precipitation. Similar conclusions on the dominating influence of summer temperatures on the tree-ring width of *Juniperus turkestanica* were made by Maksimov & Grebenyuk (1972) and Esper et al. (2003). Thus, analysis of oscillations in ΔR for *Juniperus turkestanica* and their comparison with solar activity variations (Δ^{14}C in our case) allow us to trace the relationship between long-term changes in solar activity and variations in summer temperatures in Central Asia.

It is possible to reveal long-term cyclic oscillations mainly by analyzing absolute values of series of annual tree-ring widths because the use of a running average for getting the indexes results in concealing and smoothing of large-scale fluctuations. As pointed out by Esper et al. (2003), standard formation of dendrochronological series does not allow separation out of "multi-centennial" variations in tree growth. Therefore, to reveal such climatic signals, the segment length of samples must be much greater than the selected periods of climatic signals or special methods (for example, RCS - Regional Curve Standartization Becker et al. (1993); Briffa et al. (1996) must be used to preserve multi-centennial temperature trends in palaeoclimatic reconstruction.

To reliably separate out ~200-year fluctuations in ΔR for *Juniperus turkestanica*, we analyzed the data on variations in tree-ring widths of *Juniperus turkestanica* during the last millennium obtained for the regions of Central Asia situated close to each other by three independent research teams Maksimov & Grebenyuk (1972); Mukhamedshin & Sarbaev (1988); Esper et al. (2003). The chronology of Maksimov and Grebenyuk covers the time interval from 1170 to 1970. It is based on processing the data for the trees whose ages are more than 800 years, i.e., much longer than the periodicity to be revealed. The samples were collected in Tajikistan in Tien Shan mountains on the northern slope of the Zeravshan range at altitude 3500 m, 1-1.5 km from the glacier (39.5°N, 70.7°E). The location of the site where the samples were collected is shown in Fig. 1. The chronology of Maksimov and Grebenyuk covers the time interval from 750 to 1972. It is based on processing the data for the trees whose ages range from 650 to 1250 years. The samples were collected in Kirghizia in Tien Shan mountains on the northern slope of the Alay range at the altitude higher than 2900 m (39.9°N, 72.5°E) (Fig. 1). To exclude losses of rings, both chronologies used tree sections rather than cores. The third chronology used in our work was RCS (Regional Curve Standartization) chronology of Esper et al. (2003) based on the data for *Juniperus turkestanica* cores collected in Kirghizia in northern spurs of the Alay range in Tien Shan at altitudes higher than 2900 m (39°50'-40°12'N, 71°30'-72°37'E) (Fig. 1).

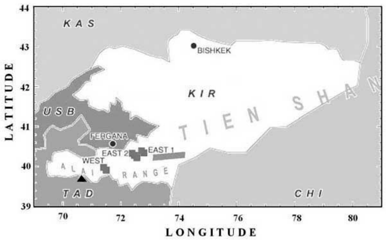

Fig. 1. The map showing locations of the sites where the dendrochronological data were collected. The triangle marks the site used by Maksimov & Grebenyuk (1972), the thick line marks the site used by Mukhamedshin & Sarbaev (1988), and the rectangle is the site used by Esper et al. (2003).

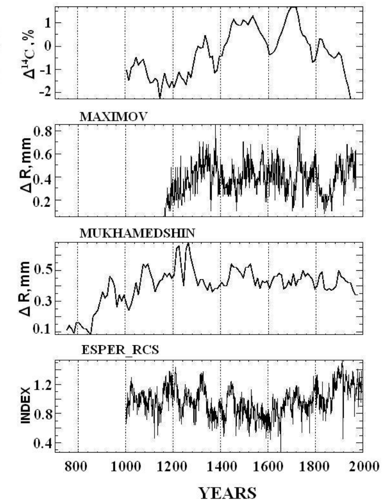

Fig. 2. From top to bottom: variations in 10-year averages of $\Delta^{14}C$ Stuiver et al. (1998); variations in tree ring widths in chronology of Maksimov and Grebenyuk; relative variations in tree ring widths in chronology of Mukhamedshin and Sarbaev (averaged over 10-year intervals); RCS chronology by Esper et al. (2003) for the last millennium.

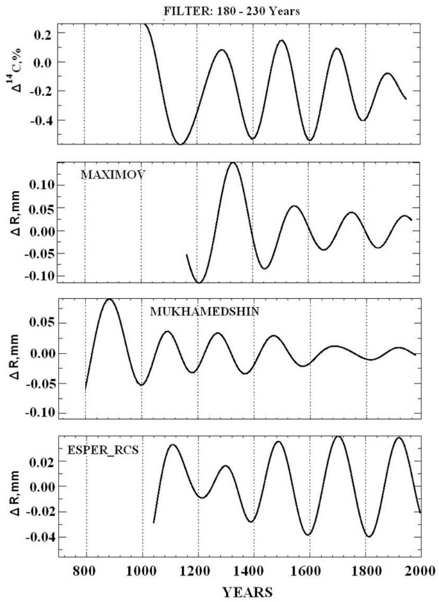

Fig. 3. Results of filtering of the data given in the range of periods 180-230 years: (from top to bottom) variations in 10-year averages of $\Delta^{14}C$; variations in tree ring widths in chronology of Maksimov and Grebenyuk; relative variations in tree ring widths in chronology of Mukhamedshin and Sarbaev (averaged over 10-year intervals); RCS chronology by Esper et al. (2003).

The time interval the RCS chronology covers is the last millennium. The chronology was put at the disposal of the authors by Dr. J. Esper.

To analyze long-term solar activity variations, the data on concentrations of cosmogenic radiocarbon ($\Delta^{14}C$) in tree rings Stuiver et al. (1998) were used in the work. For the last millennium, $\Delta^{14}C$ are averaged over 10-year intervals. The $\Delta^{14}C$ and ΔR curves for all three chronologies for Tien Shan for the last millennium are shown in Fig. 2. These data were subjected to filtering in the range of periods 180-230 years and wavelet transformation (Morlet basis) in the range of periods 100-300 years. Filtering results are presented in Fig. 3, and results of wavelet analysis are given in Fig. 4.

3. Discussion

As can be seen from Fig. 3, results of filtering of all three chronologies for *Juniperus turkestanica* (in essence, variations in summer temperatures in Central Asia) and of the $\Delta^{14}C$ curve in the range of periods 180-230 years and from Fig. 4, the results of their wavelet transformation indicate that all of them exhibit pronounced ~200-year oscillations. It is important to emphasize that a decrease in the period of quasi-two-hundred-year variations from 230 to 180 years during the last millennium is clearly observed in both $\Delta^{14}C$ and dendrochronological data (variations in summer temperatures) (Fig. 4). Therefore, dynamic spectra of changes in solar activity and climatic processes in Central Asia are similar, which points to their interrelation.

It is evident from Fig. 3, which shows results of filtering of the $\Delta^{14}C$ series and chronologies for *Juniperus turkestanica* in the range of periods 180-230 years, that the curves are syn-

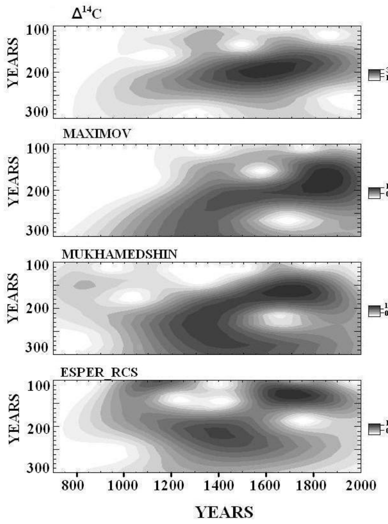

Fig. 4. Results of wavelet transformation (Morlet basis) in the range of periods 100-300 years:(from top to bottom) variations in 10-year averages of $\Delta^{14}C$; variations in tree ring widths in chronology of Maksimov and Grebenyuk; relative variations in tree ring widths in chronology of Mukhamedshin and Sarbaev (averaged over 10-year intervals); RCS chronology by Esper et al. (2003).

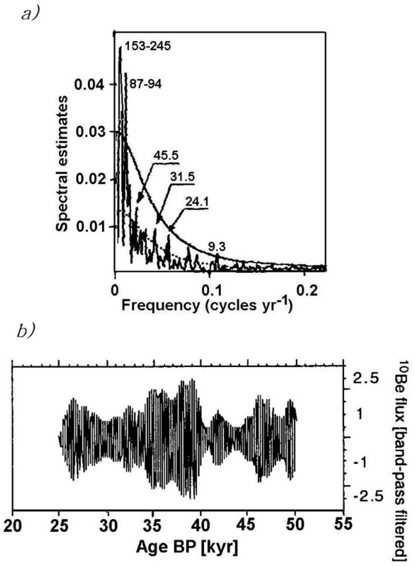

Fig. 5. (a) Spectral characteristics of subfossil 50,000 year old *Fitzroya cupressoides* collected in Southern Chile (modified from Roig et al. (2001)). (b) The de Vries solar cycle (~205 years) found by band pass filtering of the ^{10}Be flux data from GRIP (Greenland) for the period 50-25 ky BP. The deVries cycle amplitude is modulated by geomagnetic dipole changes (modified from Wagner et al. (2001)).

chronous. However, there is a phase shift between them (see Table). The phase shift between $\Delta^{14}C$ and dendrochronologies can be due to the reservoir effect in deposition of $\Delta^{14}C$ in tree rings. In addition, local climatic conditions (proximity of glaciers, etc.) can also affect the phase relation between the curves. For instance, a phase shift in glacier expansions was found for Alaska in analysis of their ~200-year variations Wiles et al. (2004).

If we take into account the phase shift, the curves shown in Fig. 3 have high correlation coefficients in the range of periods 180-230 years (see Table). For the $\Delta^{14}C$ curve and chronology of Maksimov and Grebenyuk, this coefficient reaches 0.82. High correlation coefficients are one more evidence (in addition to dynamic spectra) of the interrelation between solar activity and climatic processes

Since the revealed ~200-year climatic signal is associated with global solar forcing, it can be expected that development of the ~200-year climatic cyclicity can be detected in different regions of the Earth. The available palaeoclimatic data confirm the existence of this cyclicity in Europe, North and South America, and Asia. For instance, periodicities in expansion of Alpine glaciers (Haeberli & Holzhauser 2003) and in the varve thickness in the Holzmaar lake (Zolitschka 1996) have been observed in Europe. In Asia, 200-year temperature variat2ions were detected, besides Tien Shan, in China (Yang et al. 2002), which is also confirmed by analysis of chinese chronicles (Soon & Yaskell 2003). In North America, ~200-year climatic variations, which correlate with similar solar activity oscillations, were detected in glacier expansion in Alaska (Wiles et al. 2004) and also in variations of ring widths of bristlecone pine in Campito Mountain in eastern California (Sonett & Suess 1984). A 208-year periodicity in draughts, which cor-

Table 1. Correlation coefficients R and the phase shifts Δt (years) between curves presented in Fig. 3

	Coef. Cor. R	Δt Years
$\Delta^{14}C$ - Maksimov	0.82	40
$\Delta^{14}C$ - Mukhamedshin	0.57	0
$\Delta^{14}C$ - Esper RCS	0.52	0
Maksimov - Mukhamedshin	0.74	−60
Mukhamedshin - Esper RCS	0.75	−20

relates well with the ~200-year solar activity cyclicity was revealed for the last 2,500 years in Mexico, on the Yucatan peninsula. Besides some of the maxima in the 208-year drought cycle correspond with discontinuities in Maya cultural evolution, suggesting that the Maya were affected by these bicentennial oscillation in precipitation (Hobel et al. 2001). In South America, the 200-year periodicity was registered in variations of ring widths of subfossil 50,000-year old *Fitzroya cupressoides* in southern Chile (Roig et al. 2001) (Fig. 5a). This can be the evidence of the presence of ~200-year de Vries cyclicity in solar activity at that time. Indeed, Wagner et al. (2001) demonstrated the presence of intense variations in ^{10}Be concentrations associated with solar activity in Greenland ice for the time interval from 50,000 to 25,000 years BP (Fig. 5b). Nagovitsin & Ogurtsov (2003) demonstrated the presence of 200-year temperature variations in the Northern Hemisphere in the last millennium. These variations also correlate well with solar activity oscillations.

Thus, the ~200-year climatic oscillations associated with solar activity variations analyzed in this work manifest themselves on the global scale in not only the last millennium but also in the time interval amounting to tens of thousands years.

4. Conclusions

Our analysis of long-term dendrochrological data (*Juniperus turkestanica*) for Central Asia obtained by three independent research teams has demonstrated the presence of the ~200-year climatic variations. These variations show a high correlation (up to R= 0.82) with a similar periodicity (de Vries period) in solar activity inferred from the radiocarbon data (^{14}C). The ~200-years climatic variations manifest themselves in different regions of the Earth (Europe, North and South America, Asia etc), which points to their global character.

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