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Do Be-10 and C-14 give us the information about cosmic rays in the past?

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In the atmosphere cosmic rays produce Be-10, C-14 and other radionuclides. It is commonly supposed that the concentrations of these radionuclides (Be-10 in polar ice and C-14 in tree rings) are good proxies of cosmic ray fluxes impinging on the top of the atmosphere. But before the precipitation on the Earth's surface these elements spend several years in the atmosphere. The stirring of their concentrations over globe takes place. The analysis of 3 sets of data (2 sets of Be-10 and 1 set of C-14) shows that the correlations between them are low. Also, the relationship between cosmic ray fluxes and Be-10 concentrations in the period of 1937 – 1985 when there are direct cosmic ray flux measurements is weak. It means that the atmospheric processes, which play an essential role in the radionuclide precipitation, can violate the relationship between cosmic ray fluxes and radionuclide concentrations. We suppose that much more reliable is to use the strong relationship of sunspot number with cosmic rays to get cosmic ray fluxes in the past.

1. Introduction

The direct measurements of CR were started in 1937. They have been carried out continuously till now. It is interesting to know some proxies of CR fluxes in the past. The CR flux in upper layers of atmosphere produces a wide spectrum of secondary particles, including long-living Be-10 and C-14. The half-life of

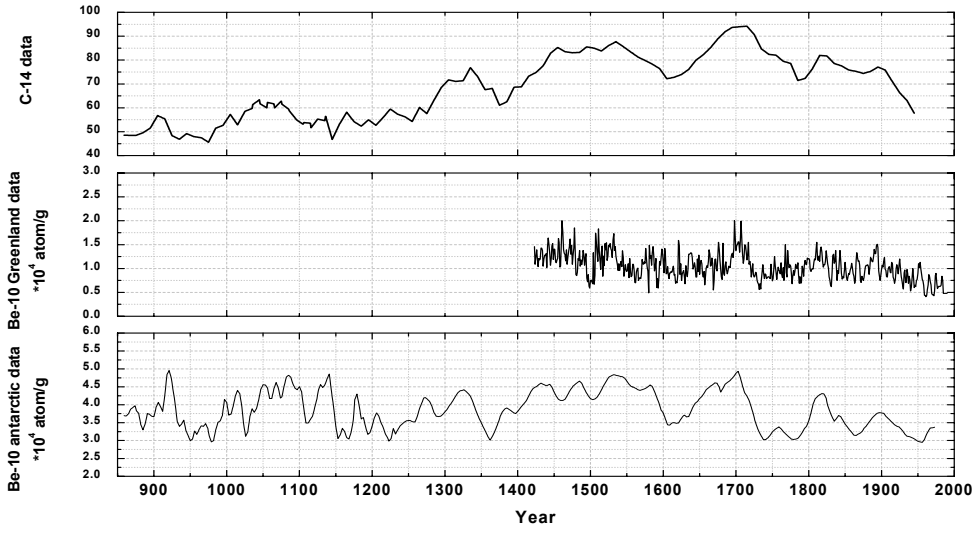

Figure 1. 10-year step C-14 data over the period since 859 till 1900; 1-year step Be-10 data from Greenland for the period since 1423 till 1985; 1-year step 22-year smoothed Be-10 data from Antarctica over the period since 859 till 1973.

Be-10 is about 1.5×10^6, and the half-life of C-14 is 5730 years. It is believed that these radionuclides can give a good approximation of CR flux in the past. After a several years spent in the atmosphere these nuclides precipitates on the Earth's surface. The Be-10 data are obtained from polar ice cores and C-14 data are obtained from tree rings. In our analysis the Antarctic (Russian station Vostok) Be-10 [1], Greenland Be-10 [2] and C-14 [3] data sets are used. These sets are shown in Figure 1.

Before precipitation on the Earth's surface the stirring of their concentrations over globe takes place. It means that atmospheric conditions in Be-10 and C-14 extraction points have an influence on its concentrations. If the value of this influence is strong, then it is difficult to make correct evaluation of CR flux in the past. Below some arguments are given to prove such conclusion.

2. Discussion

There is a large difference in the mean values of Be-10 concentrations obtained from Greenland and Antarctic ice cores. The <Be-10> concentrations in Greenland and Antarctica calculated over periods shown in the Figure 1 are 1.05 and 3.86 (in the units of 10^4 atoms/g) accordingly. The correlation between Be-10 data from Greenland and C-14 data were analyzed. After exclusion of the trend in C-14 dataset the maximum value of a correlation coefficient was 0.49 with a time shift of 6 years (see Figure 2). Such shift can be explained by the mechanisms of C-14 precipitation and accumulation. The correlation coefficient is low.

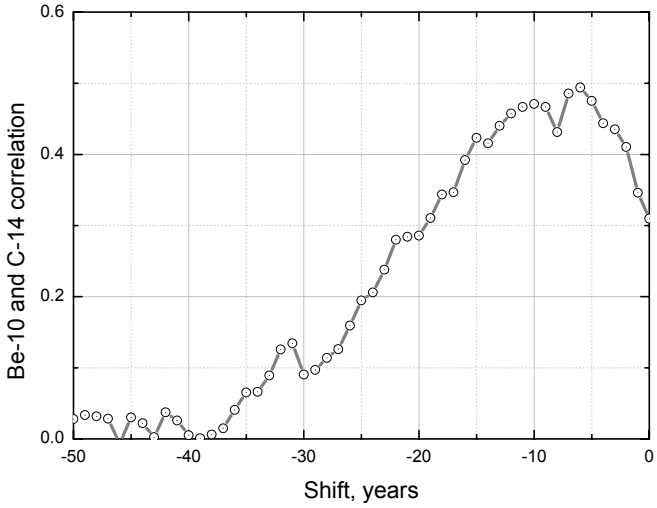

Figure 2. Correlation coefficient between Antarctic Be-10 data and C-14 data vs. time shift (C-14 – Be-10).

The analysis of Be-10 fractional ratio was made. The values of Be-10 concentrations vs time shifts relatively to the 11-year cycles of solar activity maxima and minima were taken. The fractional ratios were defined as

$$A = \frac{C_{Rz_{\min}} - C_{Rz_{\max}}}{C_{Rz_{\max}}} \times 100\%,$$

where $C_{Rz_{\min}}$ and $C_{Rz_{\max}}$ are the values of Be-10 concentrations during minimum and maximum sunspot number periods accordingly. Then the mean fractional ratio values <*A*> vs. different time shifts were calculated. The dependence of <*A*> from this time shift is shown in the Figure 3.

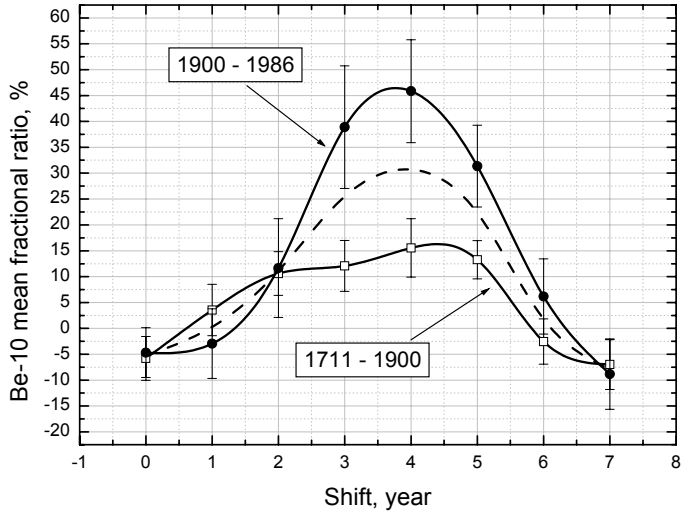

Figure 3. Be-10 concentration fractional ratios vs. time shift. Filled circles – over the period since 1900 till 1986. Boxes – over the period since 1711 till 1900. Dashed curve – average.

The maximum mean value of Be-10 fractional ratio over the period since 1711 till 1986 is 0.31 with a 4-year time shift. The mean value of the same fractional ratio for CR (particles with E > 0.1 GeV), calculated over the period since 1954 till 1981 is 2.44 ± 0.08 [4]. It means that the amplitude of 11-year modulation in CR is much bigger than in Be-10 produced by CR. The interesting fact is the difference in Be-10 mean fractional ratios over the time period under consideration (see Figure 3). We try to explain these facts by weather. One of the main weather parameter is the average atmosphere temperature. The yearly temperature data since 1879 till 1986 is used [5]. The temperature data were reduced to $dT = \langle T \rangle - T$. The time dependences of Be-10 and *dT* data and correlation between them are given in Figure 4 and Figure 5.

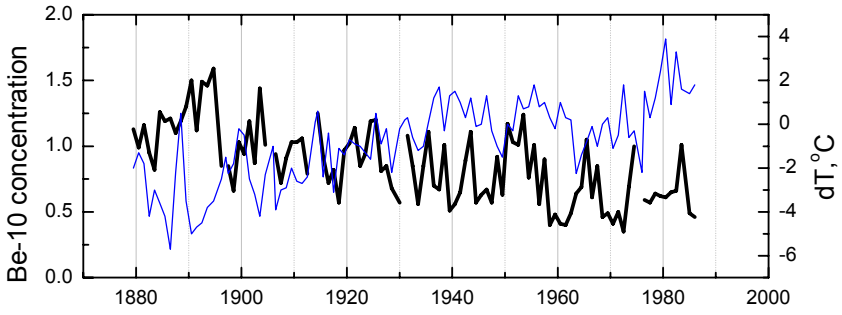

Figure 4. Be-10 concentration (thick curve) and temperature fluctuation (thin curve) vs. time.

The correlation coefficient between Be-10 concentration and temperature is – 0.54. The slope is – 0.08×10^4 Be-10 atoms/g per °C. In relative values it is 7.6 % per 1°C. These values prove the strong influence of the

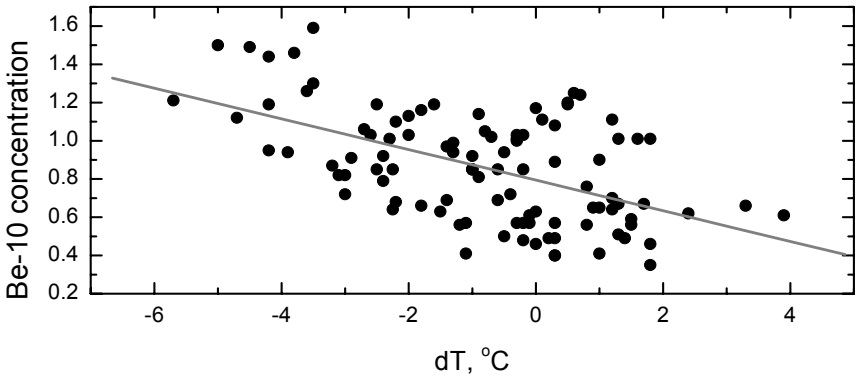

Figure 5. The correlation between Be-10 concentration and temperature.

atmospheric conditions on the concentration of Be-10. So it is necessary to take this influence into account correctly. Much more reliable is to use the sunspot number relations with the CR flux to estimate the CR in the past as it was done in the [4].

3. Conclusion

The amplitude of variation in Be-10 data is much lower than that of CR in the 11-year solar cycle. The atmospheric effects play a main role in the variations of Be-10 concentration.

4. Acknowledgements

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