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Cosmogenic Isotopes and Their Role in Present-Day Solar Paleoastrophysics

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Abstract—Present-day data on ^{14}C and ^{10}Be concentration in natural archives have been statistically analyzed. It has been established that it is difficult to extract information about solar activity variations on long (several Myr and longer) and, especially, short (to 30 years) time scales using radiocarbon data. It has been indicated that beryllium series bear reliable information about short-term, secular, and, probably, 1000-year variations in solar activity. Moreover, ^{10}Be concentration in polar ice can also be used to study the internal dynamics of solar activity. It has been concluded that beryllium data are more promising than radiocarbon ones from the viewpoint of solar paleoastrophysics.

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1. INTRODUCTION

As is known, the Sun is the main generator of many processes on the Earth and in the near-Earth space. Therefore, complex studies of the solar activity origin are not only very interesting theoretically but are also of importance for purely applied problems: space weather prediction, estimation of the solar contribution to global climate changes, and elucidation of biological consequences of solar activity fluctuations. However, the available experimental measurements of solar activity cover only three-four centuries for the sunspot number and not more than several last decades for most other solar activity parameters. Meanwhile, to solve many practical problems (to make a long-term prediction of solar activity, to study the effect of the Sun on climate), it is necessary to know the behavior of our luminary on time scales of several hundred and thousand years. To obtain similar data, one should use indirect sources of information, one of the most reliable of which is concentration of cosmogenic isotopes in the Earth's archives. Cosmogenic isotopes are generated in the Earth's atmosphere (mainly, in the stratosphere) as a result of the interaction between hadronic cascades (nucleons, peonies) generated by galactic cosmic rays (GCRs) and air atom nuclei. Since GCR flux is effectively modulated by solar activity and the geomagnetic field, the generation rate of cosmogenic isotopes substantially depends on the above factors. After formation, cosmogenic isotopes rapidly oxidize, are included in the corresponding cycles of geophysical and geochemical processes (described in [Kocharov, 1991]), and are finally deposited in polar ice (^{10}Be) and tree rings (^{14}C).

Finally, the concentration of cosmogenic carbon and beryllium in natural archives is found to be dependent on the following factors: (a) GCR flux or spectral shape in the galactic vicinity of the solar system, (b) solar activity, (c) dipole geomagnetic field, (d) global and regional climate, and (e) amount of matter brought on the Earth.

It is evident that, in spite of the potential contribution of many factors to concentration of cosmogenic isotopes, the latter should represent the most important source of information about the past of GCR flux and solar activity. The aim of the present work is to study the paleoastrophysical value of data on concentration of cosmogenic isotopes in natural archives.

2. VARIATIONS IN ^{14}C CONCENTRATION IN TREE RINGS AND SOLAR ACTIVITY IN THE PAST

In the USSR, the radiocarbon studies of solar activity in the past began as long ago as 1965–1967 within the scope of the program Astrophysical Phenomena and Radiocarbon formulated by Konstantinov and Kocharov [1965]. By the present, the sufficient amount of experimental data has been accumulated to draw some conclusions.

2.1. Short-Term Fluctuations of Radiocarbon Concentration and Solar Activity

The Maunder Minimum (MM) of solar activity (1645–1715) is one of the most interesting periods for studying short-term (lasting less than 30 years) fluctuations of tropospheric radiocarbon concentration. A special interest consists in that sunspots were almost absent during this period. Figure 1 presents results of $\Delta^{14}C$ (radiocarbon concentration with respect to the