CHAPTER 6

Tree Rings in the Study of Future Change

Chapter Leaders: L. Kairiukstis and S.G. Shiyatov
Chapter Contributors: G.E. Kocharov, V. Mazepa, J. Dubinskaite, E. Vaganov, T. Bitvinskas, and P.D. Jones

6.1. Tree Rings: A Unique Source of Information on Processes on the Earth and in Space

G.E. Kocharov

6.1.1. Introduction

The various ground-based and space-borne sensors in use today offer the possibility of detecting practically all the major kinds of corpuscular and electromagnetic radiation emanating from processes occurring on the Sun and in interplanetary and interstellar space, in real time. It would be difficult to overemphasize the importance of such studies. At the same time direct methods do not permit one to establish the characteristics of the astrophysical and geophysical processes over a large time scale. To solve these problems, which are essential for both theory and practice, one has to have eyewitnesses of the past who would be capable, as it were, not only of recording a phenomenon but of retaining the relevant information in their memory in its original form as well. Such outstanding eyewitnesses of the past are trees, which contain in their annual rings information both on the local conditions of growth and on the global properties of the Earth's atmosphere as a whole and of interplanetary space and solar activity.

Photosynthesis makes each annual ring a documentary indicator of atmospheric carbon dioxide and available soil water. The isotopic composition of wood-bound carbon depends on the dynamic characteristics of the carbon exchange reservoir and temporal variations of the cosmic ray flux incident in the Earth's atmosphere. By measuring the ^{13}C:^{12}C and ^{14}C:^{12}C ratios in tree rings, it is possible to reconstruct the variation of cosmogenic radiocarbon content in the Earth's atmosphere over a large time scale in the past. This, in turn,

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provides data on solar activity, the geomagnetic field and galactic cosmic ray flux in interstellar space. Variations in the soil chemical composition manifest themselves directly in the tree-ring composition. Therefore, the tree represents a unique detector of variations in the chemical composition of the environment both in time and in space. The information on paleotemperature becomes recorded in tree rings via the concentration ratios of the stable isotopes of hydrogen, carbon, and oxygen.

This section touches on some results obtained by *interrogating* the trees, these truly unique eyewitnesses of the past, with the aim of using the past to provide a glimpse of the future.

6.1.2. Tree rings and the deep minima of solar activity

The coordinated approach to studying tree rings (Kocharov *et al.*, 1985, and references therein) involving the radiocarbon and dendrochronological methods provides an insight into the spatial and temporal variations of the pattern of solar-terrestrial relationships. Note that while the ^{14}C content in tree rings reflects global astrophysical and geophysical phenomena (solar activity, geomagnetic fields, and climatic variations), the tree-ring width is sensitive not only to global but also to regional and local components of the environment.

The influence of the Sun on the tree-ring width can manifest itself clearly in some regions of the globe while remaining practically undetectable in other areas. This can be accounted for, on the one hand, by spatial features in the manifestation of the solar–climatic relationships. On the other hand, there are intrinsic biological reasons for the selective response of trees to qualitatively identical changes defined by the Law of Limiting Factors (Odum, 1975; Fritts, 1976); namely, if an external factor (e.g., climatic) is close to the tolerance range for a given species, it is this factor that determines the activity of the species by narrowing the tolerance range to another ecological (e.g., solar) factor. This means that under climatically extreme conditions (e.g., in temperature or precipitation), typical of the northern boundary of forests in subpolar latitudes and the upper elevation boundary of forests in mountainous areas, the sensitivity of trees to solar variations should, in principle, be higher. Therefore, we have studied (Kocharov *et al.*, 1985; Kocharov, 1986) tree-ring width variations in time from the trees that grew under extreme conditions (northern latitudes and mountainous regions). The time range studied spanned three deep minima of the solar activity, namely, the Maunder (1645–1715), Spörer (1390–1550), and Wolf (1280–1350) minima.

The data obtained are presented in *Figure 6.1.* One immediately notices deep minima in ring width that appear synchronously in all the series and coincide in time with the solar activity minima. It should be pointed out that radiocarbon content in tree rings reveals clearly pronounced maxima during deep minima in the solar activity, which can be accounted for by reduced modulation of the cosmic ray flux by the Sun. The fact that the dramatic decrease in the sunspot number, the increase of radiocarbon content, and the depression of ring width of the trees, which grew in different regions, occurred simultaneously gives