Measurements of CO_2 emission by tree rings

B.G. Ageev, V.D. Nesvetailo, Yu.N. Ponomarev, and V.A. Sapozhnikova

Institute of Atmospheric Optics,
Siberian Branch of the Russian Academy of Sciences, Tomsk
Scientific & Research Institute of Biology and Biophysics at the Tomsk State University

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A method is proposed for measuring CO_2 emission by tree rings. The method is aimed at finding new characteristics of tree rings. Rings of a Scots pine (*Pinus sylvestris L.*) and Siberian spruce (*Picea obovata Ldb.*) were taken as an object of investigation. The CO_2 concentration was measured with a laser photoacoustic gas analyzer. Positive correlation was found between the emission of CO_2 and the ring width.

Analysis of tree rings is used in dendrochronology both to reconstruct past climates and to study the effect of current climatic and edaphic conditions on tree growth.[1] This analysis is based on measurements of the width of tree rings that characterize the integral conditions for the vegetation period and changes in the environment, for example, budget of atmospheric CO_2.

Combination of the principles and methods of dendrochronology with modern techniques for analysis of specific structures of arboreal plants – tree rings – allows us to speak about formation of a new method for research into natural and anthropogenic processes and phenomena – dendrochronoindication. This method consists in establishing the dependence of some or other characteristics of tree rings on environmental factors and obtaining, on this basis, a retrospective information about processes and phenomena that determined the dynamics of these factors.[2]

By the type of problems to be solved in dendrochronoindication, they can be divided into the following fields: (1) dating of buildings, objects, phenomena, and events; (2) climate change indication (dendroclimatology); (3) indication of natural processes and phenomena, such as dynamics of solar activity, forests, forest fires, thermokarst and slope processes, etc.; (4) indication of anthropogenic effects causing changes in the environment of arboreal plants and, correspondingly, the human environment.[3]

By the type of the tree ring characteristics under analysis, we can set up three basic parts of dendrochronoindication: (1) morphometrical – based on analysis of morphometrical characteristics of tree rings (width, cross section area, shape) and incorporating most papers published in the international literature; (2) structural – based on analysis of fine structure of tree rings[4]; 3) physical-chemical – based on analysis of physical-chemical characteristics of ring wood (density, reflectivity; elemental, biochemical, and isotopic composition).[5]

The available literature data[6] evidence that living wood cells in the process of breathing produce carbon dioxide accumulated in vessels and tracheides. Since persistent membranes of wood cells are relatively impermeable for gas diffusion, the gas is accumulated in the wood in a considerable amount. It is believed, for example, that the most part of the pine trunk, except for three to four outer rings, is filled with gas, and the CO_2 concentration in the trunk is higher than in the ambient air.[6]

In this paper, aiming to find new characteristics of tree ring for use in dendrochronoindication investigations, we determine the gas composition of tree rings for Scots pine (*Pinus sylvestris L.*) and Siberian spruce (*Picea obovata Ldb*).

Materials and measurement technique

The material for sample preparation was wood of tree rings from two age groups: pine of the 70–80s and spruce of the 80–90s.

Dried wood was carefully divided layer-by-layer into rings. Analyzed samples were identical weighted portions of wood of the same ring. As was mentioned above, gas is accumulated in wood tissues impermeable for air. Therefore, we obtained gas samples by vacuum extraction. For this purpose, weighted samples were placed in sealed exposition chambers, which were pumped out for a short time (up to 3 min) up to low vacuum ($\sim 10^{-1}$ mm Hg) with following exposition for 15–20 min.

Gas analysis of the extracted gas samples was conducted by the method of laser photoacoustic (PA) spectroscopy with a tunable CO_2 laser. This method was approved by us in measurements of dark breathing of plants.[7] After the exposition, the samples from the chambers were let in the measuring cell of the PA detector and complemented with room air up to the pressure ~ 60 Torr (the range of the detector's maximum sensitivity), and this mixture has been analyzed.

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Results and discussion

The conducted measurements have shown that the gas mixture extracted from wood contained CO_2. Figure 1 depicts the data obtained and their comparison with the ring width for the both objects of study. The values of CO_2 emission show that the CO_2 concentration in the samples is higher than in air (the background value corresponds to the concentration of atmospheric CO_2 ~ 613 mg/m^3).

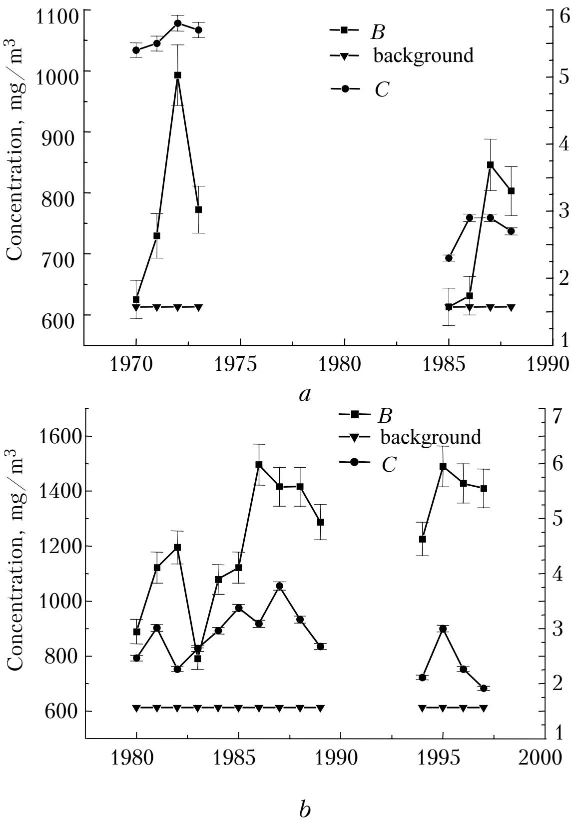

Fig. 1. CO_2 emission (B) and ring width (C) of pine (a) and spruce (b).

For the pine samples, we revealed a positive correlation between the CO_2 amount in wood and the width of the corresponding ring. To be noticed is the fact that the relative gas amount in the narrow-ring wood is higher than in the wide-ring wood.

For spruce samples, the correlation between the parameters under study is less pronounced, maybe because of the following reason. Unlike the pine tree, the spruce grew near a brook, and this caused its slope and the development of pressure and reaction wood. This, in its turn, has led to a wide variability of width of the same ring in different directions. Pine rings were much more smooth over a circle. As a result, for spruce characterization, we used the width averaged over four radii, what could contribute a certain error. Besides, tracheides of the pressure wood differ in the structure from normal rings.

Nevertheless, the data obtained clearly evidence that wood tissues actually contain the gas mixture with the CO_2 concentration higher than in air. Its variation, as well as the ring width variation, is caused by tree vital functions in some or other period and reflects the intensity of metabolism processes in the year of the ring formation.

We plan further investigations to obtain statistically ensured quantitative results. Finding the correlation between the dendrochronological data with allowance for the gas content in wood and meteorological data will allow us to obtain more complete information about vital functions of plants in different periods and under different ecological and climatic conditions. This, in its turn, will improve the accuracy characteristics of dendrochronology in paleoclimatic studies.

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