Variation of the eleven-year solar cycle during the last 1200 years and its effect on climate

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Radiocarbon is mainly produced by the incoming galactic cosmic rays modulated by solar wind and the interplanetary magnetic field, and thus its production rate and its content in the atmosphere and in the tree-rings reflect the state of solar magnetic activity. By measuring the radiocarbon contents in annual tree-rings, we can trace back the characteristics of the eleven-year solar cycles during the pre-historical periods.

The Sun holds several long-term cyclic variations in addition to the 11-year sunspot activity cycle and the 22-year cycle in the polarity reversals. The 88-year and the 208-year quasi cyclic variations of the Sun have caused several long-lasting sunspot minima such as the Maunder Minimum (1645-1715 AD), and have brought cold spells as referred as the Little Ice Age. However, not only the mechanisms of such long-term solar variations but also the mechanisms of solar influence on climate are not clarified yet.

In order to clarify the transitions of solar cycle in the past and their effect on climate, we investigated the change of the characteristics of the eleven-year solar cycle during the last 1200 years, including the grand solar activity maxima around the 9-10th century, the Spoerer Minimum (1415-1534 AD) and the Maunder Minimum by measuring the radiocarbon content in tree-rings with annual time resolution. The variation of the production rate of radiocarbon associated with the eleven-year solar magnetic activity is about 30 %. In the carbon cycle, its variation is strongly attenuated to be 1/90 of the original amplitude, and thus we need high precision measurement when we aim to detect the eleven-year variation of 14C content in tree-rings. Graphite samples were synthesized from the tree-ring samples, and the 14C/12C ratios in each graphite samples were measured using the Accelerator Mass Spectrometer at Nagoya University. The mean precision of the measurements and the amplitude of the eleven-year variation of 14C are almost comparable, but still the cycle length and the solar polarity can be determined.

The spectral analyses of the radiocarbon data have revealed the suppression of the eleven-year variations and the slight stretching of the cycle lengths during the grand activity minima. On the contrary, slight shortening of the eleven-year cycle was found for the grand solar activity maxima. The variability of the “11-year” solar cycle during the last 1200 years is 9-15 years. The “22-year” polarity reversal cycle was also modulated in association with the change of the “11-year” cycle. We compared these results with the reconstructed temperatures for the last 1200 years, and found that the significance of the “22-year” cycle is much larger than that of the “11-year” cycle especially around the grand solar minima periods. It suggests that the polarity change of the Sun is taking important role in the multi-decadal climate variations, and that the electromagnetic forcing is more important to climate rather than the irradiative outputs of the Sun such as UV radiation.