Monsoon-related errors in paleotemperature estimation based on leaf margin analysis in central Japan

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Paleotemperature reconstruction has important implications for a better understanding of present climate change. Among various paleotemperature estimation methods, Leaf Margin Analysis is a method that has been widely used by paleobotanist. In the modern flora, former researchers found that the percentage of the species with untoothed leaf margin in total woody dicot species of a flora (untoothed%) is strongly correlated to mean annual temperature (MAT). Based on this phenomenon, equations showing relationships between untoothed% and MAT have been used in paleotemperature estimation proposed as the Leaf Margin Analysis. However, untoothed%-MAT relationships are inconsistent among different regions according to previous studies. To date, eight different untoothed%-MAT equations have been proposed for different regions, although several samples from Japan are included, these sites were only obtained from limited areas close to the Pacific Ocean. However, considering various local climate conditions caused by the complex topography in Japan along with the different influence of summer and winter monsoon, the untoothed%-MAT relationship may vary among different areas in Japan, which cannot be reflected in the formerly published equations.

In this study, we aim to detect the untoothed%-MAT relationship in woody floras of central Japan. Two research areas with different climate conditions were chosen: The Pacific Ocean coastal areas and the Sea of Japan coastal areas. Based on the climate data, the Pacific Ocean coastal areas are characterized by less snow condition and higher summer precipitation affected by the activity of the East Asian Summer Monsoon. While the Sea of Japan coastal areas are characterized by heavy snow in winter, which is formed under the influence of Tsushima warm current in the Sea of Japan with East Asian Winter Monsoon, and grown season precipitation in this zone is much lower than the Pacific Ocean coastal areas.

We found that the untoothed%-MAT relationships of the two research areas are obviously different. In the Pacific Ocean coastal areas, a significant positive untoothed%-MAT relationship was detected. Compare to the other regions of the world, floras from central Japan include more species characterized by toothed-margin leaf at a given mean annual temperature. While in deep snow areas along the Sea of Japan, the untoothed%-MAT relationship becomes unclear with the effect of deep snow cover.

According to our results, paleotemperature estimated by the Leaf Margin Analysis of Japanese fossil floras may include inadequacy. The heavy snow condition along the Sea of Japan began since the middle Early Pleistocene, thus fossil floras of interglacial stages younger than that of these areas is not suitable to do the Leaf Margin Analysis. For Japanese fossil localities from areas without thick snow cover, because the untoothed%-MAT relationship of Japanese flora deviates from other regions of the world, applying these fossil floras into the formerly published untoothed%-MAT relationships will receive inaccurate paleotemperature data.

