From Canada to the Caribbean: Tree leaves control their own temperature

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The temperature inside a healthy, photosynthesizing tree leaf is affected less by outside environmental temperature than originally believed, according to new research from biologists at the University of Pennsylvania.

Surveying 39 tree species ranging in location from subtropical to boreal climates, researchers found a nearly constant temperature in tree leaves. These findings provide new understanding of how tree branches and leaves maintain a homeostatic temperature considered ideal for photosynthesis and suggests that plant physiology and ecology are important factors to consider as biologists tap trees to investigate climate change.

Tree photosynthesis, according to the study, most likely occurs when leaf temperatures are about 21°C, with latitude or average growing-season temperature playing little, if any, role. This homeostasis of leaf temperature means that in colder climates leaf temperatures are elevated and in warmer climates tree leaves cool to reach optimal conditions for photosynthesis. Therefore, methods that assume leaf temperature is fixed to ambient air require new consideration.

"It is not surprising to think that a polar bear in northern Canada and a black bear in Florida have the same internal body temperature," Brent Helliker, professor of biology in the School of Arts and Sciences at Penn, said. "They are endothermic mammals like us ,and they generate their own heat. However, to think that a black spruce in Canada and a

Caribbean pine in Puerto Rico have the same average leaf temperature is quite astonishing, particularly since trees are most definitely not endothermic. Our research suggests that they use a combination of purely physical phenomena — like the cooling from water evaporation or the warming caused by packing a lot of leaves together — to maintain what looks like leaf-temperature homeostasis."

Leaf temperature, cooled by the physiological and morphological techniques of evaporation, leaf angle or reflection and heated by a decrease in evaporation and an increase in the number of leaves per branch, can now be considered adaptations towards achieving homeostasis. Researchers do not suggest that tree canopies maintain a constant temperature through a day or a season, but rather that this ideal temperature is a long-term target value.

The research, published online in this week's *Nature*, contradicts the longstanding assumption that temperature and relative humidity in an actively photosynthesizing leaf are coupled to ambient air conditions. For decades, scientists studying climate change have measured the oxygen isotope ratio in tree-ring cellulose to determine the ambient temperature and relative humidity of past climates. The assumption in all of these studies was that tree leaf temperatures were equal to ambient temperatures.

Researchers at Penn, using measures of oxygen isotopes and current climate, determined a way to estimate leaf temperature in living trees and as a consequence showed this assumption to be incorrect.

This is an unfortunate finding for the potential to reconstruct climate through tree-ring isotope analysis but a boon to ecologists because it creates potential for the reconstruction of tree responses to both average climate and climate change over the last couple of centuries.

The continental-scale dataset used in this research was part of a separate study done by Suzanna Richter, a contributor to this study and post-doctoral researcher in the Department of Earth and Environmental Science at Penn. "Multi-million-year-old wood that colleagues and I collected in Arctic Canada and Siberia was so well preserved that it both looked like modern wood and burned like modern wood. Its fantastic preservation brought about questions as to whether the chemistry of the wood could be used to determine the climate that the trees grew in millions of years ago."

Although there are few studies that compare tree-canopy temperatures throughout an entire growing season, a recent study using infrared thermal imaging of a mixed forest in Switzerland agreed with the current study: canopy temperature was 4-5 degrees (Celsius) higher than the cool, ambient air temperature of Switzerland.

Source: University of Pennsylvania