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Thermal buffering by forest canopies investigated through remote sensing and IoT sensor networks.

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Forests exert a strong buffering effect on below canopy air temperature, lowering daytime maxima and increasing winter minima. Moreover, forest composition and structure deeply condition the microclimate within and above the forest environment, affecting all its living organisms and their biological processes. Standard meteorological measurements of air temperature—according to WMO recommendations—are not performed under forest cover, thus not adequately representing the temperature regimes driving processes such as photosynthesis, respiration, transpiration, and which serves as environmental cues in regulating leaf and growth phenology. Current forest biogeochemical models rely on gridded temperature data derived from standard meteorological stations and satellite-derived land surface temperatures as drivers to simulate how carbon, nitrogen and water cycles are affected by climate change, potentially leading to biased estimates. Recent availability of low-cost IoT temperature sensors enables the development of dense networks within forest environments, making multi-year, multi-site, high-spatiotemporal resolution microclimate monitoring increasingly feasible.

In this ongoing study focusing on six sites in northeastern Italian Alps, we compared in-situ air temperature data collected by IoT based sensors below canopies with measurements collected on towers above forest canopies, and with canopy surface temperatures estimated from remote sensing. By integrating these datasets with tree forest inventory data and LiDAR-derived canopy structure metrics, we aimed to quantify the magnitude of canopy thermal buffering and its variation across forest types, canopy structures, diurnal and seasonal cycles and microclimatic conditions. Additionally, we explored the resistance of the buffering effect during drought and heatwave periods.

By yielding more realistic temperate values at which functional processes occur, this research will improve our capacity to study forest ecophysiological responses to climate warming.