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Thermal homoeostasis of forest canopies: a neglected process for the evaluation of land surface models

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MODIS daytime observations of land surface temperature over intact, well-watered forests globally were compared to WFDEI three-hourly air temperatures interpolated to the overpass times of the Terra and Aqua satellites. In agreement with predictions from energy balance theory, land surface and air temperatures were found to "cross over" around 25˚C. At cooler air temperatures forest canopies are warmer than air while at warmer air temperatures they are cooler than air. This phenomenon is observed across all forest types and latitudes and explains, among other things, the adaptive advantage of large leaves in the moist tropics. However, among current models, offline dynamic vegetation models make no distinction between leaf and air temperatures. Land surface models included in Earth System models simulate the canopy energy balance but how realistically they do so has not been investigated. One current land-surface model (JULES) has been shown not to be able to reproduce the characteristic daytime cooling of tropical forest canopies in particular. Several possible issues might contribute to this problem, including incorrect representation of soil moisture and its effect on transpiration rates; incorrect temperature optima of photosynthesis, leading to stomatal closure at high temperatures; and an incorrect model for stomatal response to high vapour pressure deficit (vpd). Potential consequences for climate change prediction are severe because of the risk of over-estimating the impact of high air temperatures and/or vpd on tropical forests.