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Large and problematic gradients in temperature and VPD in field research settings

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Temperature and vapor pressure deficit (VPD) are fundamental drivers of plant ecophysiological function, and developing conceptual and predictive frameworks describing how photosynthesis, stomatal conductance, and transpiration respond to (and modify) these drivers is an long-standing research challenge. At the plant- and ecosystem-scale, much of our understanding of these processes has been derived by linking whole plant responses (e.g. from flux towers, sap flow, etc) to the temperature and VPD of the air measured some horizontal or lateral distance away from the plants themselves. However, thermodynamic processes frequently promote large gradients between canopy leaf and air temperatures, with tremendous variations across vertical and horizontal gradients. Here, we will synthesize observations from >100 flux towers to show that this difference can amount to 10 degrees C (or more), especially on hot summer days when heat impacts are most deleterious. The gradient between canopy and air temperature is not well explained by plant functional type, albedo, or climate, but are clearly related to canopy height and the dynamics of evapotranspiration. These profound differences in canopy versus air temperature translate into large (e.g. >5 kPa) differences between the VPD of the air and the vapor pressure differences experienced by leaves. Empirically derived sensitivities of stomatal conductance and photosynthesis to VPD are likely overestimated when the VPD of the air is used as a proxy for the vapor pressure difference experienced by plants. These biases can obscure our species-level understanding of how gas exchange responds to VPD and become especially problematic when observed sensitivities are compared with theoretical expectations or implemented in models that do not account for VPD gradients. We will conclude by discussing some strategies to limit these biases in field settings.