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Estimating sensible heat flux in agricultural screenhouses by the flux-variance and half-order time derivative methods

Ori Achiman, Yonatan Mekhmandarov, Moran Pirkner, and Josef Tanny
Agricultural Research Organization, Institute of Soil, Water and Environmental Sciences, Bet Dagan, Israel
(tanai@volcani.agri.gov.il)

Previous studies have established that the eddy covariance (EC) technique is reliable for whole canopy flux measurements in agricultural crops covered by porous screens, i.e., screenhouses. Nevertheless, the eddy covariance technique remains difficult to apply in the farm due to costs, operational complexity, and post-processing of data – thereby inviting alternative techniques to be developed. The subject of this research was estimating the sensible heat flux by two turbulent transport techniques, namely, Flux-Variance (FV) and Half-order Time Derivative (HTD) whose instrumentation needs and operational demands are not as elaborate as the EC. The FV is based on the standard deviation of high frequency temperature measurements and a similarity constant C_T. The HTD method requires mean air temperature and air velocity data. Measurements were carried out in two types of screenhouses: (i) a banana plantation in a light shading (8%) screenhouse; (ii) a pepper crop in a dense insect-proof (50-mesh) screenhouse. In each screenhouse an EC system was deployed for reference and high frequency air temperature measurements were conducted using miniature thermocouples installed at several levels to identify the optimal measurement height. Quality control analysis showed that turbulence development and flow stationarity conditions in the two structures were suitable for flux measurements by the EC technique. Energy balance closure slopes in the two screenhouses were larger than 0.71, in agreement with results for open fields. Regressions between sensible heat flux measured by EC and estimated by FV resulted with C_T values that were usually larger than 1, the typical value for open field. In both shading and insect-proof screenhouses the C_T value generally increased with height. The optimal measurement height, defined as the height with maximum R^2 of the regression between EC and FV sensible heat fluxes, was just above the screen. C_T value at optimal height was 2.64 and 1.52 for the shading and insect-proof screenhouses, respectively, with $R^2 = 0.73$ in both types of structures. FV data analysis of the temperature signal at frequencies lower than 10 Hz showed that R^2 of these regressions was insensitive to the data analysis frequency up to 0.5 Hz. This suggests that turbulent transport in the screenhouses was governed by large scale vortices. Regressions between EC and HTD sensible heat fluxes resulted with R^2 which slightly decreased with height and had values between 0.3 and 0.4 for both screenhouses. The regression slopes also decreased with height and had values between 0.4 and 0.6. We conclude that in screenhouses the FV technique provides a more reliable estimate of the sensible heat flux than the HTD; however, the latter is simpler and more robust in terms of equipment, operation and data analysis and hence may be more attainable for day-to-day use by the growers.