

**Surface energy imbalance:  
an investigation using the flux variance and surface renewal methods**

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Energy imbalance problem with the eddy covariance (EC) technique has been extensively investigated in the past decades. Recent reviews reported that the imbalance was approximately 10-30%, mainly attributed to the underestimation of energy fluxes at a single plot. In this study, we analyzed the sensible (H) and latent (LE) heat fluxes estimated using the flux variance (FV) and the surface renewal (SR) methods. We used the data observed at two sites. One is the rice paddy in a humid area, located in Shouxian of Anhui Province; another is the wheat field in a semi-arid area, located in Changwu of Shanxi Province. For the rice paddy, FV and SR methods were in good agreement with EC measurement in estimating H, and obtained LE that was 1.2 times of EC measures. Both FV and SR methods obviously improved energy balance closure by 10% on average. For the wheat field, H estimated from either method was slightly lower than EC measures; while LE was higher than EC measures. The sum of H and LE was close to EC measurement. Furthermore, we used the Bowen ratio calculated from the SR estimates for the unstable atmospheric condition. The Bowen ratio was less than that from EC measures over the rice paddy, while it was more than that from EC measures over the wheat field. Overall, the two methods were consistent at the same site but showed different performance for different sites, which was likely attributed to different moisture conditions. Further analysis is under going to provide a more insightful investigation on the energy imbalance issues.

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