

A comprehensive evaluation of MODIS-based water use efficiency with global eddy covariance flux data and a process model

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Ecosystem water use efficiency (WUE), defined as the ratio of gross primary productivity (GPP) to evapotranspiration (ET), is an important indicator to investigate the interaction between the terrestrial carbon and water cycles. The spatiotemporal patterns of WUE inferred from MODIS GPP and ET products and its responses to environmental factors have been analyzed, however, the accuracy of MODIS-derived WUE (MODIS WUE) has not been well evaluated. In this study, we evaluated monthly and annual MODIS WUE using global covariance flux data (FLUXNET2015 dataset) during 2000-2014, and conducted global intercomparisons (2001-2011) among annual WUE from MODIS, gridded FLUXNET (MTE) and a process model (BESS). Site scale (53 sites) evaluation results revealed that MODIS gave reliable estimates for GPP and ET, however, the performances of MODIS WUE was poor for monthly WUE ($R^2=0.14$) and even worse for annual WUE ($R^2=0.08$). MODIS WUE was generally underestimated with a bias of $-0.21 \text{ gC kg}^{-1} \text{ H}_2\text{O}$ (-8.43%) and RMSE of $1.20 \text{ gC kg}^{-1} \text{ H}_2\text{O}$ for monthly WUE, and a bias of $-0.28 \text{ gC kg}^{-1} \text{ H}_2\text{O}$ (-11.31%) and RMSE of $0.98 \text{ gC kg}^{-1} \text{ H}_2\text{O}$ for annual WUE. Among all land cover types, MODIS WUE performed relatively better in savannas and woody savannas for monthly WUE and grasslands for annual WUE, but significantly overestimated WUE in open shrublands. Likewise, MODIS WUE was obviously overestimated in hot and cold semiarid and arid climate zones. The global intercomparison results demonstrated that the spatial pattern of MODIS WUE was broadly similar to that of MTE and BESS WUE, except for the tropical and subtropical arid and semiarid areas. In these regions MODIS WUE showed extremely high values with large uncertainty and different linear trends compared with MTE and BESS WUE. These disagreements were mainly caused by the discrepancies in MODIS ET. Therefore, the uncertainty of MODIS WUE in the tropical arid and semiarid areas should be taken with caution when using MODIS WUE to investigate and interpret how WUE varies spatially and its responses to climate change. Furthermore, the accuracy of MODIS GPP and ET datasets should be paid extra attention since the quality of both GPP and ET would directly affect the WUE accuracy.

Keywords: Water use efficiency (WUE), Evaluation, Intercomparison, MODIS, FLUXNET, BESS



