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Benchmarking global land surface models in CMIP5: analysis of ecosystem water use efficiency (WUE) and Budyko framework

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Twelve Earth System Models (ESMs) from phase 5 of the Coupled Model Intercomparison Project (CMIP5) are evaluated in terms of ecosystem water use efficiency (WUE) and Budyko framework. Simulated values of GPP and ET from ESMs were validated against with FLUXNET measurements, and the slope of linear regression between the measurement and the model ranged from 0.24 in CanESM2 to 0.8 in GISS-E2 for GPP, and from 0.51 to 0.86 for ET. The performances of 12 ESMs in simulating ET are generally better than GPP. Compared with flux-tower-based estimates by Jung et al. [Journal of Geophysical Research 116 (2011) G00J07] (JU11), all ESMs could capture the latitudinal variations of GPP and ET, but the majority of models extremely overestimated GPP and ET, particularly around the equator. The 12 ESMs showed much larger variations in latitudinal WUE. 4 of 12 ESMs predicted global annual GPP of higher than 150 Pg C year-1, and the other 8 ESMs predicted global GPP with $\pm$15% error of the JU11 GPP. In contrast, all EMSs predicted moderate bias for global ET. The coefficient of variation (CV) of ET (0.11) is significantly less than that of GPP (0.25). More than half of 12 ESMs generally comply with the Budyko framework but some models deviated much. Spatial analysis of error in GPP and ET indicated that model results largely differ among models at different regions. This study suggested that the estimate of ET was much better than GPP. Incorporating the convergence of WUE and the Budyko framework into ESMs as constraints in the next round of CMIP scheme is expected to decrease the uncertainties of carbon and water fluxes estimates.