Evapotranspiration

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Accurate evapotranspiration (ET) estimation is important in understanding the hydrological cycle and improving water resource management. The operational simplified surface energy balance (SSEBop) model can be set up quickly for the routine monitoring of ET. Several studies have suggested that the SSEBop model that simulated ET has performed inconsistently across the United States. There are few detailed studies on the evaluation of ET simulated by SSEBop in other regions. To explore the potential and application scope of the SSEBop model, more evaluation of the ET simulated by SSEBop is clearly needed. We calculated the SSEBop model-based ET ($ET_{SSEBopYRB}$) with the input of MOD11A2 and climate variables in the Yellow River Basin (YRB), China. We also compared the $ET_{SSEBopYRB}$ with eight coarse resolution ET products, including China ET_{MTE} produced by the upscaling energy flux method, China ET_{CR} generated by the nonlinear complementary relationship model, three global products based on the logic of Penman-Monteith (ET_{PMLv2}, ET_{MODIS} and ET_{BESS}), two global ET products based on the surface energy balance (ET_{SEBS}, $ET_{SSEBopGlo}$), and integrated ET products based on the Bayesian model averaging method (ET_{GLASS}), by the annual ET derived from the water balance method (WB-ET) in fourteen catchments. We found that $ET_{SSEBopYRB}$ and the other eight ET products were able to explain 23 to 52% variability in water balance ET of fourteen small catchments in YRB. $ET_{SSEBopYRB}$ has better agreement with WB-ET than ET_{SEBS}, ET_{MODIS}, ET_{CR} and ET_{GLASS}, with a lower RMSE (88.3 mm yr^{-1} vs 121.7 mm yr^{-1}), higher R^2 (0.49 VS 0.43) and lower absolute RPE (–3.3% VS –19.9%) during the years 2003–2015. We also found that the uncertainties of the spatial pattern of the average annual ET and the ET trend are still large in different ET products. Third, we found that the free global ET product derived from the SSEBop model ($ET_{SSEBopGlo}$) highly underestimated the annual total ET trend of the YRB. Poor performance of the land surface temperature product of MOD11A2 in 2015 caused the large $ET_{SSEBopYRB}$ uncertainty at eight-day scale and monthly scale. Further evaluation of the ET based on the SSEBop model in site measurements is needed.

Keywords: Model comparison ; SSEBop ; Yellow River Basin ; evapotranspiration ; land surface temperature ; MOD11A2 ; MYD11A2

The extensive evaluation of ET estimates is necessary before they are used in various applications [31]. A comprehensive evaluation of SSEBop and MODIS ET over the CONUS indicates that SSEBop showed better performance for grassland and forest classes and effectively reproduced the basin scale ET response [31]. Singh et al. (2013) estimated the Colorado River Basin ET by applying Landsat images and SSEBop, finding that the SSEBop model nicely captured the annual ET variability at the site level and sub-basin level [25]. Other research also reported that the SSEBop model performed well over CONUS, with an R^2 of 0.86 between the estimated ET and the ET of 42 flux tower sites from 2001–2007 [32]. In the Midwestern United States, the validation of estimated ET by SSEBop using Landsat images captured the spatial and temporal variation in ET with a low root mean square error and high R^2. However, SSEBop was consistently the worst-performing model among SEBAL, METRIC, S-SEBI, SEBS and SSEBop and overestimated ET at all sites when estimating humid southeastern United States ET by Landsat imaging from 2000–2010 [33], indicating its limited applicability in the southeastern US. A sensitivity research of SSEBop ET in the CONUS demonstrated that the SSEBop model was most sensitive to land surface temperature and reference ET, differential temperature, and maximum ET scalar [32]. Therefore, the accuracy of the ET derived from the SSEBop model varies from place to place depending on the accuracy of input parameters including climate data and calibration data [30], which indicates that the magnitude and annual trend of ET still have large uncertainties [34]. The validation and application of SSEBop concentrated on the CONUS. There is a clear need to evaluate ET derived from SSEBop in other regions such as China and Europe to reduce uncertainty in the regional ET variation and to prioritize studies of the water cycle, land-atmosphere interaction, and water management [35, 36].

We conducted a comparison of ET derived from the SSEBop model using the water-balance ET in a highly spatially heterogeneous river basin of the YRB and reached the following conclusions. During the years 2003–2015,

(1) $ET_{SSEBopYRB}$ and the other eight ET products were able to explain 23 to 52% variability in WB-ET of fourteen small catchments in YRB. $ET_{SSEBopYRB}$ has better agreement with WB-ET than do ET_{SEBS}, ET_{MODIS}, ET_{CR} and $ET_{GLASS,}$ with lower RMSE (88.3 mm yr^{-1} vs 121.7 mm yr^{-1}), higher R^2 (0.49 VS 0.43) and lower absolute RPE (–3.3% VS -19.9%).

(2) The free global ET product derived from the SSEBop model highly underestimated the annual total ET trend of the YRB. More validation regarding this product is required in other regions using site measurements (e.g., eddy covariance flux tower measurements).

(3) The abnormal data in the land surface temperature products of MOD11A2 in 2015 limited the performance of the SSEBop model at eight-day scale and monthly scale. Future studies will explore the use of MYD11A2.

(4) On the basin scale, the uncertainties of the ET trend and spatial pattern are still large indifferent ET products. We need to further reduce the ET uncertainty to better serve water resource management and ecological restoration project construction.
