Irrigation is an important component of the terrestrial water cycle, but it is often poorly accounted for in models. When included, irrigation often relies on simplistic assumptions such as soil moisture deficit approaches. In the last years, methods have been developed to detect and quantify irrigation by making use of satellite remote sensing data. Recent developments have attempted to integrate satellite data and land surface models via data assimilation (DA) to (1) detect and quantify irrigation, and (2) better model the related land surface variables such as soil moisture, vegetation, and evapotranspiration. In this study, different synthetic DA experiments are tested to advance satellite DA for the estimation of irrigation. We assimilate synthetic Sentinel-1 backscatter observations into the Noah-MP model coupled with an irrigation scheme. When updating soil moisture, we found that the DA sets better initial conditions to trigger irrigation in the model. However, large DA updates to wetter conditions can inhibit irrigation simulation. Building on this limitation, we propose an improved DA algorithm using a buddy check approach. The method still updates the land surface, but now the irrigation trigger is not based on the evolution of soil moisture, but on an adaptive innovation outlier detection, making the trigger observation-based.

The new method was tested with different levels of model and observation error. For mild model and observation errors, the DA outperforms the model-only 14-day irrigation estimates by about 30% in terms of root-mean-squared differences, when frequent (daily or every other day) observations are available. The improvements can surpass 50% for high model errors. However, with longer observation intervals (7 days), the system strongly underestimates the irrigation amounts. White noise in the signal has a milder impact on the performance, reducing the improvement by 10% compared to the assimilation of perfect observations. The method is flexible and can be expanded to other DA systems and to a real-world case.