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Interactive comment on "Evaluation of global terrestrial evapotranspiration by state-of-the-art approaches in remote sensing, machine learning, and land surface models" *by* Shufen Pan et al.

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To Reviewer #2:

General Response: We appreciate the reviewer for the positive comments. We have addressed the stated comments point-by-point. Below are the reviewer's comments, followed by our responses and changes in manuscript.

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[Reviewer #2 General Comment] This paper was already well-written, especially for the detailed discussion of limitations and possible next steps of different ET products. The

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reviewer thus has a few minor suggestions for the authors to consider. [Response] We appreciate the reviewer for the positive comments.

[Reviewer #2 Specific Comment 1] The remote-sensing based, machine learning, and LSMs ET were comprehensively intercompared. However, how is the performance of ET outputs from the Earth system models (e.g., those from CMIP5 and CMIP6) and the reanalysis? There must be a reason why the authors did not include them. But please clarify this or add these comparison results. [Response] Thanks for pointing out this issue. We didn't include ET outputs from the Earth system models (e.g., those from CMIP5 and CMIP6) because previous study confirmed systematic biases in global terrestrial ET estimated by CMIP5 models (Mueller and Seneviratne, 2014) and CMIP6 data were not available when we conducted our analyses. Reanalysis systems which are built upon the assimilation of extensive disparate observations in a physically consistent manner are capable of providing the estimates for a broad range of variables (Balsamo et al., 2015; Rienecker et al., 2011). ET estimates derived from both atmospheric and off-line land reanalysis datasets have been evaluated at local, regional and global scales (Baik et al., 2018; Feng et al., 2019; Mao and Wang, 2017) and have been compared with estimates from other approaches (Jimenez et al., 2011; Mueller et al., 2013; Mueller et al., 2011). The objective of this study is to identify the uncertainty sources in each type of ET estimations. However, these reanalysis systems integrate multiple process modules, multi-source remote sensing observations and ground-based measurements, and multiple assimilation algorithms, which lead to the mixture of systematic errors and make it hard to identify the sources of errors in ET estimations at the global scale. For above-mentioned reasons, our analyses didn't include ET outputs from the Earth system models and the reanalysis.

[Reviewer #2 Specific Comment 2] In lines 245-246, you indicated the benchmarking products are from the machine learning and physical-based satellite datasets. It seems confusing both here and in Figs 3, 5, and 7. For example, in Fig. 7, if the benchmark product is the simple combination of the two data [Response] The ensemble mean of benchmark products was calculated as the mean value of all machine learning and physical-based satellite estimates (6 datasets for Fig. 3 and 5, and 5 datasets for Fig. 7) rather than the mean value of machine learning ensemble mean and satellite ensemble mean, since we treated each benchmark dataset equally. We have added the sentence describing the calculation of the ensemble mean of benchmark products in Section 2.2 The ensemble mean of benchmark products was calculated as the mean value of all machine learning and physical-based satellite estimates, since we treated each benchmark dataset equally.

[Reviewer #2 Specific Comment 3] The Abstract seems quite long. Please double check if the Abstract length fits this particular journal. [Response] We have double checked journal's requirements for manuscript, there is no particular limitation on the length of abstract. Following your comment, we have shortened the abstract. Evapotranspiration (ET) is a critical component in global water cycle and links terrestrial water, carbon and energy cycles. Accurate estimate of terrestrial ET is important for hydrological, meteorological, and agricultural research and applications. However, direct measurement of global terrestrial ET is not feasible. Here, we first gave a retrospective introduction to the basic theory and recent developments of state-of-the-art approaches for estimating global terrestrial ET, including remote sensing-based physical models, machine learning algorithms and land surface models (LSMs). Then, we utilized six remote sensing-based models (including four physical models and two machine learning algorithms) and fourteen LSMs to analyze the spatial and temporal variations in global terrestrial ET. The results showed that the mean annual global terrestrial ET ranged from 50.7×103 km3 yr-1 (454 mm yr-1) to 75.7 ×103 km3 yr-1 (697 mm yr-1), with the average being 65.5×103 km3 yr-1(588 mm yr-1). LSMs had significant uncertainty in the ET magnitude in tropical regions especially the Amazon Basin, while remote sensing-based ET products showed larger inter-model range in arid and semi-arid regions than LSMs. LSMs and remote sensing-based physical models presented much larger inter-annual variability (IAV) of ET than machine learning algorithms in southwestern U.S. and the Southern Hemisphere, particularly in Australia. LSMs suggested stronger control of precipitation on ET IAV than remote sensing-based models. During 1982-2011, the ensemble remote sensing-based physical models and machine-learning algorithm suggested significant increasing trends in global terrestrial ET at the rate of 0.62 mm yr-2 ($p<0.05$) and 0.38 mm yr-2 ($p<0.05$), respectively. In contrast, the ensemble mean of LSMs showed no statistically significant change (0.23 mm yr-2, $p>0.05$), even though most of the individual LSMs reproduced the increasing trend. Moreover, all models suggested a positive effect of vegetation greening on ET intensification. In general, the ensemble means of the three ET categories showed generally good consistency, however, considerable uncertainties still exist in both the temporal and spatial variations in global ET estimates. The uncertainties were induced by multiple factors, including parameterization of land processes, meteorological forcing, lack of in situ measurements, remote sensing acquisition and scaling effects. Improvements in the representation of water stress and canopy dynamics are essentially needed to reduce uncertainty in LSM-simulated ET. Utilization of latest satellite sensors and deep learning methods, theoretical advancements in non-equilibrium thermodynamics, and application of integrated methods that fuse different ET estimates or relevant key biophysical variables will improve the accuracy of remote sensing-based models.

[Reviewer #2 Specific Comment 4] In line 483, Fig. 5 does not have subfigures. [Response] We are sorry for the wrong numbering. “Fig. 5c-d” in our previous manuscript should be “Fig. 8c-d”. We have corrected this error in the main text.

References Baik, J., Liaqat, U.W., Choi, M. (2018) Assessment of satellite- and reanalysis-based evapotranspiration products with two blending approaches over the complex landscapes and climates of Australia. Agricultural and Forest Meteorology 263, 388-398. Balsamo, G., Albergel, C., Beljaars, A., Boussetta, S., Brun, E., Cloke, H., Dee, D., Dutra, E., Muñoz-Sabater, J., Pappenberger, F. (2015) ERA-Interim/Land: a global land surface reanalysis data set. Hydrology and Earth System Sciences 19, 389-407. Feng, T., Su, T., Zhi, R., Tu, G., Ji, F. (2019) Assessment of actual evapotranspiration variability over global land derived from seven reanalysis datasets. International Journal of Climatology 39, 2919-2932. Mao, Y., Wang, K. (2017) Comparison of evapotranspiration estimates based on the surface water balance, modified PenmanâĂŘMonteith model, and reanalysis data sets for continental China. Journal of Geophysical Research: Atmospheres 122, 3228-3244. Mueller, B., Hirschi, M., Jimenez, C., Ciais, P., Dirmeyer, P., Dolman, A., Fisher, J., Jung, M., Ludwig, F., Maignan, F. (2013) Benchmark products for land evapotranspiration: LandFlux-EVAL multi-data set synthesis. Hydrology and Earth System Sciences. Mueller, B., Seneviratne, S.I. (2014) Systematic land climate and evapotranspiration biases in CMIP5 simulations. Geophysical Research Letters 41, 128-134. Rienecker, M.M., Suarez, M.J., Gelaro, R., Todling, R., Bacmeister, J., Liu, E., Bosilovich, M.G., Schubert, S.D., Takacs, L., Kim, G.-K., Bloom, S., Chen, J., Collins, D., Conaty, A., da Silva, A., Gu, W., Joiner, J., Koster, R.D., Lucchesi, R., Molod, A., Owens, T., Pawson, S., Pegion, P., Redder, C.R., Reichle, R., Robertson, F.R., Ruddick, A.G., Sienkiewicz, M., Woollen, J. (2011) MERRA: NASA's Modern-Era Retrospective Analysis for Research and Applications. Journal of Climate 24, 3624-3648.

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