RC1: 'Comment on essd-2023-466', William Kustas, 27 Mar 2024

The paper by Bartkowiak et al on the application of remote sensing-based energy balance model (TSEB-PT) in the Mediterranean region is well written with a robust scientific approach and analysis. However, there are two areas that the authors need to address in order for the reader to have a better understanding of the uncertainty in both the model and measurements. It appears the authors have chosen several challenging sites (some in complex topography) to conduct their model application and validation. This requires them to discuss in greater detail the measurement uncertainty. For example, they should make mention of the kind of energy balance closure they obtain at the different sites and if they used some method to force closure. Merely providing a reference to the processing of the eddy covariance data isn't sufficient for the reader to easily interpret these results. In addition, for sites with sloping/complex terrain do they know if a planar fit was incorporated in post-processing the eddy covariance measurements (e.g., Ross and Grant, 2015)? Do the sites with complex topography have worse energy balance closure than more flat terrain? If so, this could factor into larger scatter observed at those sites. Finally, TSEB was not originally developed to be applied in complex terrain, although ways to incorporate refinements to TSEB for complex terrain is a worthwhile endeavor and should be mentioned.

I would also like to draw their attention to other studies that have been able to find better results over forested sites, although still a tendency for larger scatter (Hadi et al., 2022). Others have accounted for the green fraction from remote sensing and PT alpha term from knowledge of land cover (Guzinski et al., 2013; Andreu et al., 2018). Of course one may consider adjusting the PT alpha term a kind of tuning, but I am sure the authors are aware that land cover information should be used wherever possible since knowledge of the land cover type factors into a number of the TSEB-PT model parameters. Finally, there are other studies applying the multiscale version of TSEB that have obtained good results over pine forests (Yang et al 2017; 2020). Although the authors do point out that some of the sites are challenging, I think they should also reference work that suggests applications of TSEB over forested areas can achieve reasonable results, especially when the surface is not complex.

References:

Andreu, A., Kustas, W.P., Polo, M.J., Carrara, A., & González-Dugo, M.P. (2018). Modeling surface energy fluxes over a dehesa (oak savanna) ecosystem using a thermal based two-source energy balance model (TSEB) I. *Remote Sensing, 10,* doi:10.3390/rs10040567

Guzinski, R., Anderson, M.C., Kustas, W.P., Nieto, H., & Sandholt, I. (2013). Using a thermal-based two source energy balance model with time-differencing to estimate surface energy fluxes with day-night MODIS observations. *Hydrol. Earth Syst. Sci., 17,* 2809-2825

Jaafar, H.H., Mourad, R.M., Kustas, W.P., & Anderson, M.C. (2022). A global implementation of single and dual-source surface energy balance models for estimating actual evapotranspiration at 30-m resolution using Google Earth Engine. *Water Resour. Res.*, 58, doi:10.1029/2022WR032800.

Ross, A.N. and Grant, E.R. (2015) A new continuous planar fit method for calculating fluxes in complex, forested terrain *Atmos. Sci. Let., 16,* 445–452

Yang, Y., Anderson, M.C., Gao, F., Hain, C.R., Semmens, K.A., Kustas, W.P., Normeets, A., Wynne, R.H., Thomas, V.A., & Sun, G. (2017). Daily Landsat-scale evapotranspiration estimation over a managed pine plantation in North Carolina, USA using multi-satellite data fusion. *Hydrol. Earth Syst. Sci., 21*, 1017-1037

Yang, Y., Anderson, M., Gao, F., Hain, C., Noormets, A., Sun, G., Wynne, R., Thomas, V., & Sun, L. (2020). Investigating impacts of drought and disturbance on evapotranspiration over a forested landscape in North Carolina, USA using high spatiotemporal resolution remotely sensed data. *Remote Sens. Environ.*, *238*, 111018

Dear William, thank you very much for your review and useful comments.

First, we would like to explain the measurements uncertainty at the validation sites. Indeed, when all input parameters were available, we have computed the energy balance closure (EBC) ratio (i.e., [Rn-G-H]/LE with Rn: net radiation, G: soil heat flux, H: sensible heat flux, LE: latent heat flux) for the EC sites. In total, the EBC values are derived for five flux sites in Italy. The obtained ratios are as follows:

- vineyard at IT-Lsn (1 m a.s.l.): 0.28,
- grassland at IT-MtM (1450 m a.s.l.): 0.08,
- grassland at IT-MtP (1550 m a.s.l.): 0.13,
- evergreen broadleaf forest at IT-SR2 (4 m a.s.l.): 0.73,
- grassland at IT-Tor (2160 m a.s.l.): -0.02.

After contacting providers of daily flux data from University of Ghent in Belgium, we were recommended to include all eight sites in our analysis due to the small number of EC towers over our study areas. We derived the largest ratio over lowland forest at IT-SR2 exceeding 0.7, while EBC values over sloping terrain (i.e., IT-MtM, IT-MTP, and IT-Tor) achieved acceptable scores (i.e., below 0.2). Unfortunately, for the remaining three sites the EBC ratios were not provided (i.e., FR-Pue, IT-Ren, IT-MBo). As can be seen above, in our case, the energy balance closure values do not depend on topographic complexity. On the other side, to make any conclusions in this regard, we truly believe that the impact of complex topography on energy balance closure shall be further investigated by incorporating more flux sites across different landcovers, topographies, and (micro)climates. We contacted PIs of the EC towers to understand if they applied a planar fit method to eddy covariance flux data. We have received their feedback regarding sites over forested landscapes at FR-Pue, IT-Ren and IT-SR2, and high-mountain grasslands located in Aosta Valley (IT-Tor) and Mazia Valley (IT-MtM and IT-MtP). The first two tree covered sites (FR-Pue, IT-Ren) were processed using a double rotation method, while a planar fit method was applied to IT-SR2. Regarding the alpine grasslands, all eddy covariance flux sites were corrected with a planar fit approach. In addition to the research work of Ross and Grant (2015), we have included ancillary studies investigating EC measurement uncertaintities:

1. Castelli, M., Anderson, M.C., Yang, Y., Wohlfahrt, G., Bertoldi, G., Niedrist, G., Hammerle, A., Zhao, P., Zebisch, M. and Notarnicola, C., 2018. Two-source energy balance modeling of evapotranspiration in Alpine grasslands. Remote Sensing of Environment, 209, pp.327-342.
2. Mauder, M., Cuntz, M., Drüe, C., Graf, A., Rebmann, C., Schmid, H.P., Schmidt, M. and Steinbrecher, R., 2013. A strategy for quality and uncertainty assessment of long-term eddy-covariance measurements. Agricultural and Forest Meteorology, 169, pp.122-135.
3. Rannik, Ü., Vesala, T., Peltola, O., Novick, K.A., Aurela, M., Järvi, L., Montagnani, L., Mölder, M., Peichl, M., Pilegaard, K. and Mammarella, I., 2020. Impact of coordinate rotation on eddy covariance fluxes at complex sites. Agricultural and Forest Meteorology, 287, p.107940.

Description on measurements uncertaintities was added in the revised version of the manuscript in the section 2.2 (lines 189-193), and also it has been discussed in the 'Results and discussion' (lines 479-482) and in the Conclusions (lines 642-644).

Second, we fully agree with you that more attempts are required to enhance the TSEB performance over heterogenous terrain. This is a part of our current work where we aim to improve the model in the European Alps, including forest sites and areas with complex topography. In this regard, topographically corrected solar radiation and landcover at finer spatial resolutions shall be incorporated to account for heterogenous landscapes and different types of vegetation along with their biophysical characteristics. Moreover, as mentioned by you before, the Priestely-Taylor parameter with a default value of 1.26 needs to be adjusted to take into account variations in green vegetation cover during growing season. All described above improvements are our close-future objectives in order to derive more reasonable results, especially over forests as shown in the suggested reference research studies. To improve our manuscript, in the section 4.1 (lines 485-497) we have added some text where together with the suggested reference papers we describe potential improvements in the TSEB-PT for deriving more robust ET estimates over forests and areas with complex topography. Additionally, in the revised manuscript we included the following research publication on TSEB modelling over boreal forests:

1. Cristóbal, J., Prakash, A., Anderson, M.C., Kustas, W.P., Alfieri, J.G. and Gens, R., 2020. Surface energy flux estimation in two Boreal settings in Alaska using a thermal-based remote sensing model. *Remote Sensing*, *12*(24), p.4108.