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Discussions
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Interactive comment on "The effect of water storage change in ET estimation in humid catchments based on Budyko framework and water balance models" *by* Tingting Wang et al.

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Response:

The authors appreciate the reviewer for helpful and constructive comments that improved our original manuscript. We have addressed the comments below and made corrections. The changes being made are marked in revised version in the manuscript.

The authors perform a multi-method assessment of ET in wet basins in Southern China and attempt to assess the role of assuming change in water storage as negligible (DS=0) in their calculations at the annual and muti-annual time scales. They also

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propose that this assumption may be the cause of poor annual ET estimates from three models (Fu, abcd and Xin'anjiang model) when compared to the ET from the water budget estimate at the annual scale. They find that including the estimates of Delta S at the annual scale from the abcd model reduces the variability of ET predictions. I think the subject is interesting and is nowadays gaining a lot of attention due to the wide use of the Budyko-type studies. The use of the abcd model to calculate DS sounds like a good idea, and to compare ET Budyko with ET Budyko + ΔS. The scientific basins of this study is sound, at least from what I managed to extract from the extremely-difficult-to-understand manuscript. The exploration of change in water storage is interesting and resourceful (Fig. 7-10). But I have some concerns that must be fixed in this manuscript:

1. Language. As it is now, I think the manuscript is unpublishable in HESS or any other decent scientific journal. The use of English is of poor quality. Some parts of the manuscript cannot be judged with scientific criteria because it is just impossible to understand what the authors are referring to. I myself do not have English as a native language, so I understand how frustrating it is to express your findings in another language. However, this manuscript needs to be written from beginning to end with the aid of a native English speaker. I recommend taking it to a professional writer or similar. I started fixing grammatical issues, but then I realized there was no case in doing this and I should better focus on the science.

It is really nice of you for being so considerate but it is our mistake. We feel terribly sorry for all the inconvenience we made here. We have sought help from a native speaker, who is a postdoctor in hydrology, to revise the manuscript. Much improvement has been made in the revised version in hoping that this version is readable and interesting to you.

It is worth mentioning that we have added the result about the effect of ΔS on annual ET estimation based on Budyko framework in section 3.3. It shows that almost no improvement has been made in annual ET estimation based on the extended Budyko

equation (Figure 6), which uses P-ΔS as 'equivalent' precipitation at monthly timescale through high R2 achieved (Figures 5 and 6), which is due to the seasonal pattern within the year. This further supports our conclusion that the common practice of ignoring annual ΔS in water balance, can lead to larger deviation in estimated ET assessment in humid catchments. Without reliable ΔS, ET estimation in humid catchments remains an important scientific challenge.

<Figure 5 here> <Figure 6 here>

2. Literature review on water storage and Budyko needs to be improved and updated. The authors have omitted important pieces of research dealing with the importance of water storage changes within the Budyko framework and specifically in "wet" regions. Some examples, -[Moussa and Lhomme, 2016] – This study should give some insight on the possible mathematical formulations that the authors could further explore, apart from their multimethod assessment. [Jaramillo and Destouni, 2015] – I know that the basins that the authors are studying are "humid", so irrigation is highly unlikely. However, flow regulation by water impoundment in reservoirs or water transfers affect the evaporative ratio ET/P in the long term, and it is not due to the water stored in the reservoirs as the authors suggest by citing Mao (2016). They find that flow regulation acts like a proxy of land and water use that can explain ET/P changes more than PET/P changes. [Destouni et al., 2013] – Budyko analysis cannot get "wetter" than in cold and wet Sweden. This study shows that accounting for surface water storage changes at the annual scale does not change long-term trends in basin-scale ET/P. [Gudmundsson et al., 2016] – They find that changes in water availability are only dominated by changes in the aridity index in very humid climates

We are really appreciate your helpful and constructive comments. We have rewritten the introduction as suggested, and detailed review about water storage change is in lines 68-80 and liens 99$\sim$116 in the revised introduction. The recommended references are really helpful and we have cited some of them, along with some new ones in the text.

3. I think the authors need to be clearer in what they refer with DeltaS. Moisture S and storage S. How can we know which is which. Is ï ËŻADËĞ ΔS=ΔS+ΔG.

Thank you for your suggestion. The ΔS is the soil moisture change plus ground water change. We have revised this as suggested in lines 72-73, and detailed introduction for China in lines 364-371 in revised manuscript. As for soil moisture change and ground water change, we use symbols Smt and Gt in the abcd model in the revised manuscript to show the difference. Thank you.

4. I think they should justify their work in a better way. Saying that the effect of storage change in ET calculations in wet regions is scarce is just not true.

Excellent advice to the point. Thank you. We have altered this (lines 64-80) and some other sentences that are vague and confusion, e.g., the highlight. “We highlight that the common practice of ignoring annual ΔS in water balance, can lead to larger deviation in estimated ET assessment. Without reliable ΔS, ET estimation in humid catchments remains a challenge in bridging our gap in our knowledge of the hydrologic cycle.”

We originally wanted to express that “there is currently limited research containing humid catchments only, and most inter- and intra-annual ET estimation research are focusing on areas containing both humid and non-humid catchments.” Sorry about our mistakes as such.

5. What is the multiannual scale? How did you measure DS (storage, not moisture) at this scale? How is it different from the annual scale? This is not clear at all. You never specify the periods

The multiannual timescale is the multi-year averages, here is the averages of P, Q and ET for ∼50 years. The ΔS is the soil moisture change plus ground water change. At multiannual timescale, ΔS =P-Qobs-ETBudyko, and the ΔS is quite small (averages around 1mm). While at annual timescale, we obtained the ΔS from abcd output, and variation of this annual ΔS is relatively large, -50 ∼ +50 mm/yr, and the values in some

years are larger than this range. Thank you.

6. Line 420 to 421. The improvement of R2 from 0.02 to 0.58 sounds quite extraordinary. You should show this scatter plot due to its importance

Done! We have added it in Figure 9b as suggested. Thank you.

<Figure 9 here>

Other issues: 49. controlled instead of captured 58. around the globe: : : and scales like 60. region(s), research is limited 71 Delete “exist” 81-82 This is obvious. 86 theoretical ET 89 specifically 105. Again, this is because not all drivers of change are taken into account with Budyko-type models. 111 “It would prone”? 183 proved 257. Excellent? Change this word 282 Terrestrial feature? 306. You should state p-values for all R2 values that you give 356 “launched”

Done. We have revised as suggested. Since the whole manuscript has been rewritten, and some of the changes are untraceable in the revised manuscript. But we have learned quite a lot during the process. Thank you.

303. Why do you use the NSE. For what? Explain

We use NSE to evaluate the runoff simulation, and it is just my favor in the first. We then take a deeper thought, and it is unnecessary since there are similarity between NSE and R2. So we use R2 instead throughout the text. Thank you.

90. The Mao study has one big problem. They calculate Δ"ET"= ΔP-ΔR-ΔS and not Δ"ET"=ΔP-ΔR-Δ(ΔS), which is incorrect. That is why they get such a big effect of storage change in the ET calculations.

Sounds reasonable and refreshing, and it is definitely worth a deeper thought. But the conclusion like “the ΔS is not approximate zero annually” can be concluded, but we have removed the detailed description from the text. Thank you.

64-66 This is because these models do not account for all drivers of change in

ET/P. For instance, look at [Jaramillo and Destouni, 2014]. 74% of all movements in Budyko space cannot be explained by only changes in PET/P during long periods of time. Jaramillo, F., and G. Destouni (2014), Developing water change spectra and distinguishing change drivers worldwide, Geophys. Res. Lett., 41(23), 8377–8386, doi:10.1002/ 2014GL061848.

In our opinion, the poorly estimated annual ET is due to the ignoring of the variation of annual ΔS in ETwb in humid region, as we have presented the analysis in sections 4.3 and 4.4. Besides, at multi-annual timescale, the Budyko equation can well estimate ET as ΔS is approximately zero, which can be well explained by PET/P. Besides, the vast research in arid and semiarid region have shown that, the Budyko equation can well estimate ET at annual and multi-annual timescales when validated against ETwb since their ΔS can be seen as zero in ETwb.

Figure 6- Something does not fit here. ET+S+Q=ET/P?? Sometimes I feel that there is a confusion between variability, variance and R2. Please check this along the manuscript.

ET+ΔS +Q=P. As below, the Figure 6 is now Figure 7 in revised manuscript. The ETwb is P-Qobs when we ignored the variation of annual ΔS, as common practice. Then the ETbudyko is validated against this ETwb, and the larger this annual ΔS is, the greater the bias will be to the assessment. We stop using variance in the context to avoid such confusion. Thank you for your suggestions.

<Figure 7 here>

53. What is humid= PET/P<1?

The humid catchments we used are defined by aridity index (PET/P) <1, line 215.

61-64 Could not understand this

We have deleted this sentence since it is deviated from our major purpose. In the submitting version, we want to show that, the proportional relationship exists in humid

catchments, but the estimated ET is not well when compared with ETwb.

224 Is DS = DG + DS? You have to differentiate storage from soil moisture, they are both S and confuses.

We have revised this and use symbol Sm to represent soil moisture change. Thank you truly.

342-349 Improve language. Impossible to understand due to the language.

Thank you and we have rewritten these sentences, lines 360∼363. “From another perspective, the neglecting annual ΔS in water balance has prone to errors associated with ungauged subsurface runoff transfer in humid catchments. Therefore it produces relatively unreliable ETwb as real ET in hydrology and the assessment of modelled ET. ”

Caption of Figure 1: The aridity index should be < 1, instead of > 1.

Done, sorry about this mistake. Thank you.

Please also note the supplement to this comment:
http://www.hydrol-earth-syst-sci-discuss.net/hess-2017-151/hess-2017-151-AC2-supplement.zip

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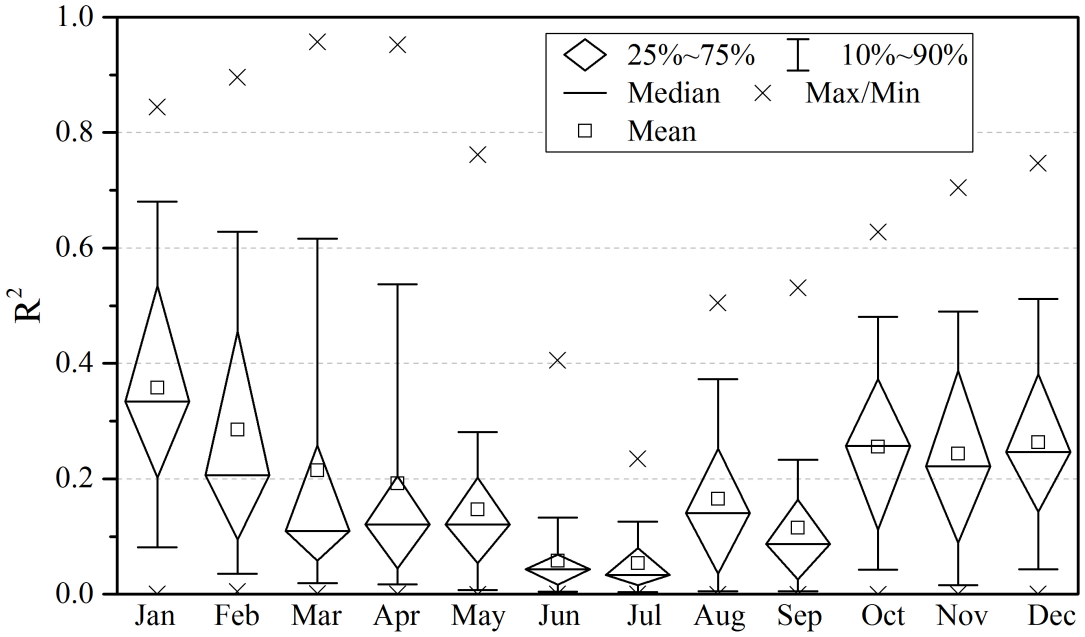

Fig. 1. Figure 5 The box plot of R2 between monthly ETwb and ETbudyko using the extended Budyko equation, i.e., P-ΔS as equivalent P, and ΔS is obtained from abcd model.

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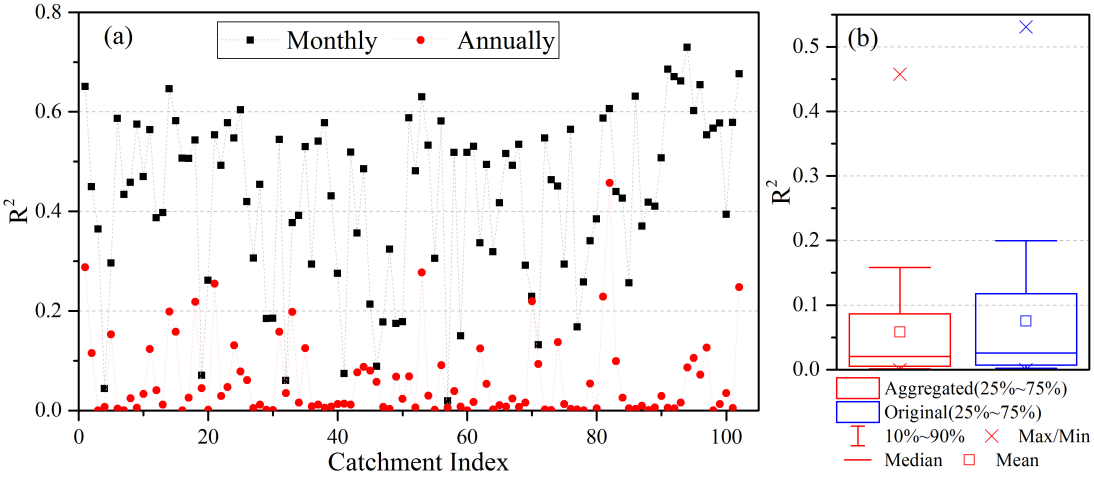

Fig. 2. Figure 6 The R2 between ETwb and ETBudyko at monthly timescale and that aggregated to annual timescale in (a), and (b) the boxplot of R2 of this aggregated annual ETbudyko and the original R2 of annua

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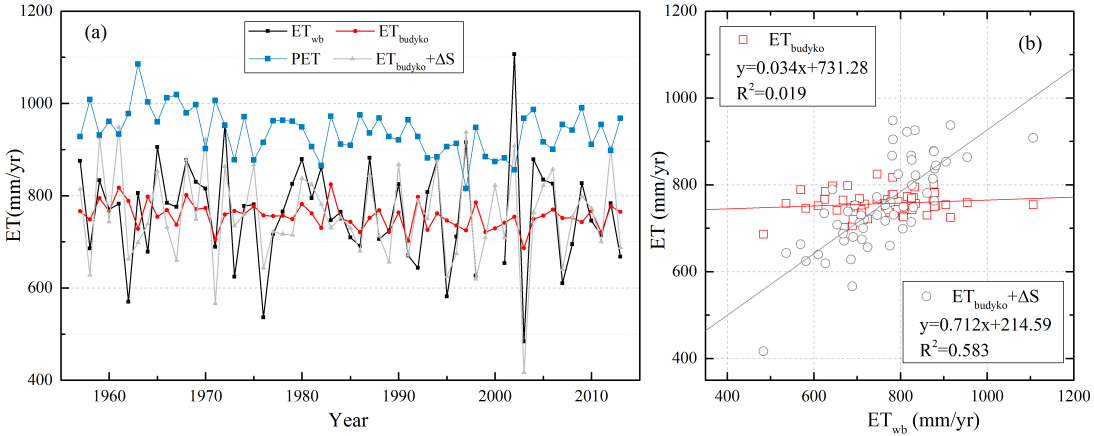

Fig. 3. Figure 9 The annual time series of PET, ETwb, ETbudyko and ETBudyko + ΔS over 1957-2013 for the selected typical catchment (a), and (b) the comparison between ETbudyko, ETBudyko + ΔS against ETwb in t

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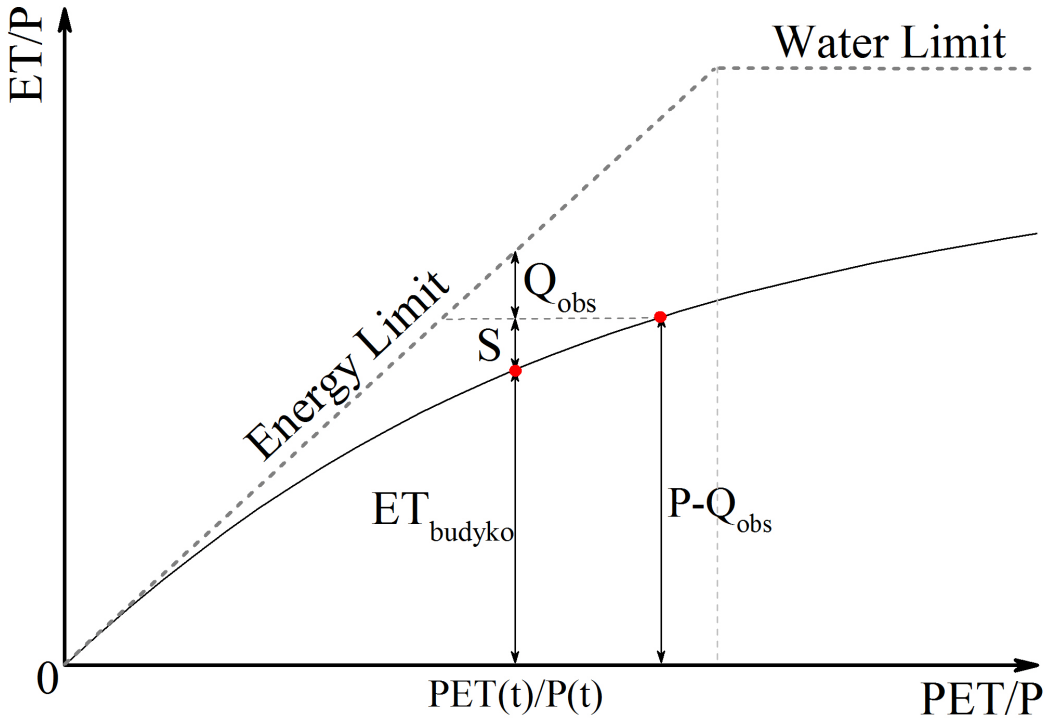

Fig. 4. Figure 7 The schematic of ΔS in Budyko equation in humid catchments (energy limited). ETbudyko is estimated based on given P and PET, and validated against ETwb, i.e., P-Qobs-ΔS where ΔS∼0.

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