Interactive comment on "The Budyko framework beyond stationarity" *by* P. Greve et al.

Anonymous Referee #2

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The manuscript by Greve et al. extends the Budyko framework to include the effect of non steadiness and especially seasonality in water storage. Even though I think it is a good idea I have some major concerns regarding the derivation and some of the assumptions used. Also the time scale of analysis should be made very clear (this is similar to a comment posted by another reviewer). Also it should be made very clear that a major disadvantage is to add many parameters (many y_0's for each month) to get the correct ET.

Major issues - Assumption equation 7 seems incorrect. If $E <= E_p$ then $-E >= -E_p$ and $(P-E)/E_p >= -1$. (It would be nice to add this directly in the text) but the second assumption of positive definiteness is not correct or at least it very much depends on the time scale you are considering. There should be much more substantial discussion on this. Also the assumption $dE/dE_p = 0$ at $-y_0$ is not valid (see several work on the Bouchet

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Morton relationship, e.g. by Brutsaert). - Equation 10 is not correct or at least again the assumptions behind it should be discussed. Indeed the min function is not linear. - y_0 should be time varying and it is indeed what you present in Fig 9. There should be a clear discussion on this and the fact that to really represent the seasonal cycle we would need at least 12 values (in fact more because interannual variability would change y_0). - Throughout the manuscript some physical interpretation is missing and some steps of the derivation could be added (see specific comments below). At this point the manuscript appears more as a manipulation of Fu's equation with little link to intrannual storage. - The manuscript is really ostly on seasonal storage effect so you should make this very clear upfront

Specific points p6800 lines 8-9: the water balance is always closed what you meant I think is negligible storage p6801 before equation 1 define the time scale of applicability and the fact that Budyko only applies on large-scale to remove groundwater contribution improve the clarity of paragraph after equation 1: why would it be only a problem with supply it is steady for both line 4: You should cite Zhou et al. 2015 GRL, which is close to your derivation Change "complex hybrid of various"... Equation 2 is missing groundwater and you should state that it is valid at the watershed level otherwise you need to include lateral flow p6802: in fact multi-year varilability has to be avoided for the budyko framwework to be valid, this should be discussed clearly line 6: even on interannual time scales Budyko is not valid (see carry over effect of water storage so that the budyko curve can be higher than 1 for instance) Equations 3 and 4: have a look at Zhou et al. 2015 GRL p6805: y_0 is really a function of time, you should comment on this line 7: $y_0 = 1$ you could mention that this is when $E = E_{max} = E_p$. Also you should clearly define E_p because E can be larger than E_p in many cases (because of roughness or large LAI) p6806 can you give more physical explanation after equation 11 section 5: please carefully discuss the time scale effect Also Penman Monteith should be Penman for potential evaporation. What is done for the reference roughness? What do you consider as a reference, this is important. p6809: define your frequency of y_0 computation end of section 5: you should have a discussion on the fact that you have

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added many parameters to really retrieve E (see Fig 9) so it is not really a predictive model but more a model for physical interpretation. Also the main trouble is that we do not have access to E at the watershed scale so how can this be used on water shed data where P and Q only are measured? p6811 line21: physically well defined: in fact it is more mathematically defined some physical explanation would be nice. Equation A1: can you give further steps for this equation? Derivation A2 to A8 is very elegant. Figure 9: we really need at least monthly estimates of y_0 to get ET right so why not run a simple water balance model?