We appreciate Dr. Donohue's quick response on our manuscript and apologize for our delayed replay due to the other busy works.

Dr. Donohue regarded that the problem of the evaporative ratio ($F$) being greater than 1 in the Budyko space ($F$-$\phi$ coordinates) is an artificial problem because of misunderstanding and misapplication of the original Budyko framework. Then, he questioned on the objective of the manuscript at two points and focused on the understanding of the water and energy supplies in the Budyko framework.

We totally agree that the Budyko framework should be carefully applied when the actual supply of water for evapotranspiration (ET) is not limited by rainfall in an accounting period. As Dr. Donohue pointed out, in this situation the Budyko framework should be modified to include other sources (groundwater or/and change in storage) of water for ET. And then, Dr. Donohue suggested that we should evaluate the performance of the standard Budyko model with the modified definition of water supplies. It is a very good suggestion, which will be accepted in revise the manuscript.

Accordingly, in this discussion, two concerned questions need to be analyzed and we would like to present our results for further discussions.

**1. Conceptual aspects of Budyko framework, Budyko space and Budyko curves**

What is ***Budyko framework***? Even though the definition of the term has never been clearly presented in the literature, we would like to propose a preliminary summation according to previous studies, including Donohue (2007):

(1) The first hypothesis in Budyko framework is the "limits" concept that $ET$ is controlled by energy limitation (represented by the potential $ET$) when the water supply is ample, otherwise is controlled by the limitation in the water supply when the energy supply is ample.

(2) The second hypothesis in Budyko framework is the steady state concept, by which the water balance at the catchment scale could be written as $P$=$E$+$Q$ with the mean fluxes. It is acceptable for mean annual water balance behavior in long-term with steady climate. The function of this hypothesis is to limit the water supply for $ET$ as the unique flux, $P$.

(3) The third hypothesis following the previous two assumptions, which should be considered as the meat of the Budyko framework, is that the relationship between $E/P$ and $E_0/P$ could be generally represented by a single curve (Budyko, 1958) below the bound lines determined by the hypothesis-1. In the last decades, the single curve has been replaced by a group of curves dependent on a specific parameter that represents different types of catchments. This is a revision of the original ***Budyko curve*** but remain the feature of $E/P$<1. The Budyko curves yield an interpretation on how the catchments in the world are located in the Budyko space.

In such a Budyko framework, the relationship between the water supply and evapotranspiration is simply delineated with the $F$-$\phi$ coordinates that now we defined as ***Budyko space***. It becomes a favorable way to understand the water balance behaviors of catchments. However, the hypothesis-2 significantly limits the application of Budyko framework so that a lots of researchers expected to apply or extend Budyko framework for estimating annual or even monthly ET. This is not the original Budyko framework but in terms of Budyko-type framework or modified Budyko framework.

We recommended to keep the definition of Budyko space as that determined in the coordinates of $E/P$ and $E_0/P$. This is because the definition of the aridity index ($E_0/P$) for mean annual or annual patterns has been widely accepted in both hydrologic and climatologic studies. In addition, the ET ratio ($E/P$) was also frequently used to evaluate the response of water balance at catchments on the climate change. It allow us to delineate, observe and compare the status of water balance in a catchment at different time-scales and check how the actual annual ET deviates from the original Budyko framework.

The objective of our manuscript is to see how the annual water balance would be in the original Budyko space and what is the role of groundwater dependent evapotranspiration.

**2. The performance of the modified Budyko space**

It is an alternative approach to extend Budyko framework using modified definition of Budyko space (include other components of the water supply) yet remain the hypothesis-1 in the original Budyko framework, as Dr. Donohue suggested in the comments. This approach faces on the difficulty in accounting for the change in storage and the amount of "plant-available-ground water". Among the components of the water supply, precipitation is almost independent on ET whereas the others are coupling with the ET process. Complexity of the relationship arises due to this coupling behavior and may beat the conventional formulas for Budyko curves in the new Budyko space.

The annual water balance of a catchment could be expressed as

$$P - \Delta S = E + Q \tag{1}$$

where $\Delta S$ is the increment of water storage in the catchment. The LHS of the equation refers to the water supply (supply of groundwater for ET is included in $-\Delta S$). The modified Budyko space is formed by $E_0/(P-\Delta S)$ and $E/(P-\Delta S)$.

In the manuscript, we presented the plots of the catchment annual water balance on such a new Budyko space. As shown in Figure 10, the original Budyko curve is not available to capture the shift path of the catchment in the modified coordinates.

We did not check the validity of other formulas of the Budyko curves in the manuscript but we have the results as shown in the following Figure 1. One can immediately found that none of the Budyko curves can capture the shift path of the annual water balance in this catchment.

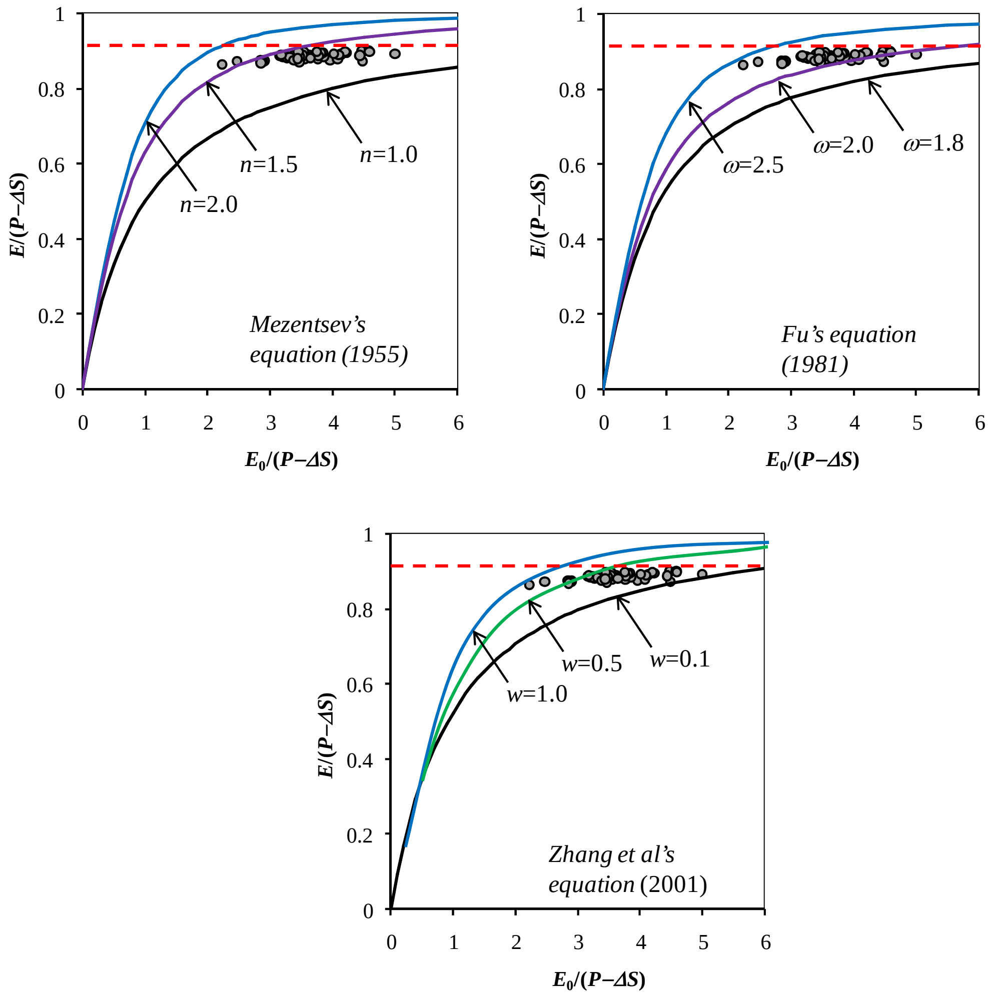


**Figure 1** Plots of the annual water balance at the HRC, China, in the modified Budyko space (dots) and the Budyko curves determined with different formulas. The red dashed line indicates the possible bounded ET in the water limited condition.

Another essential feature in Figure 1 is that the $E/(P-\Delta S)$ seems not bounded by 1 but is approximately bounded by 0.9. This would be not satisfied by the hypotheisis-1 in the Budyko framework. An interpretation presented in the manuscript (at the end of Section 4.3) is the necessary contribution of $P-\Delta S$ to the annual runoff, about 10%. It is not a surprising case in the unsteady state because decrease in groundwater storage could be supplied to both evapotranspiration and streamflow.

It can be argued that is using $P-\Delta S$ also a misunderstanding of the water supply for ET process in an unsteady condition? However, even such debates on the definition of the water supply are positive for persist in the hypothesis-1, they do not make sense on solve the problem because of the complex coupling between the unsteady water supply and ET. Anyway, it is not the focus of the manuscript. Our efforts is to reveal the impact of groundwater dependent ET on shift of the annual water balance in the Budyko space.

**References:**

Donohue R. J., M. L. Roderick, and T. R. McVicar. 2007. On the importance of including vegetation dynamics in Budyko’s hydrological model. *Earth Syst. Sci.*, 11, 983–995.