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Discussions

Interactive comment on "Derivation of the mean annual water-energy balance equation based on an Ohms-type approach" *by* X. Shan et al.

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The paper aims for a physically based derivation of the mean water and energy balance equation. The authors use a description of water vapor transfer between catchments and describe the fluxes in a flux gradient approach. Imposing the Budyko hypothesis then yields the well known Mezentsev-Choudhury-Yang equation. I think that a general derivation of the Budyko or the MCY equation is of high interest for hydrological research and thus of interest for HESS. However, one of aims of this paper is a rigorous derivation which reflects hydrological understanding. To be honest, I find it difficult to understand the reasoning which form the basis for the derivation. What I do not understand is the framework of water vapor transfer between catchments (illustrated in the figures). Figure 1 and 2 show a moisture transfer from one catchment to the next

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Discussion paper

(downwind?) where the input of the next catchment is set by the evaporation of the first. This then leads to their statement that after n catchments there is no water left and E = 0. However, in reality there are also other sources of vapor which can contribute to precipitation in catchment 2 and these are being neglected. So this framework is not intuitive to me. The main derivation is illustrated with figure 3 where 4 different nodes are introduced. With corollary 2 it is stated that the resistance nAB 6= n1 arguing that there are other possible routes between the node Atmosphere A and the catchment node B, namely atmosphere A to atmosphere C to catchment D to catchment B. I did not understand this water transfer between the two catchments. I am also not sure if these assumptions and the ones in stated in section 2.1 are actually relevant for the derivation described in section 3. Therefore I recommend major revisions which should particularly improve the description to enable the reader to better understand how considering hydrological processes lead towards the MCY equation.

Response:

We thank the reviewer very much for taking the time to review our manuscript and for the invaluable comments. And we will carefully revise the manuscript following the comments and suggestions to enable the reader to better understand. I am sorry that we didn't describe the catchment network clearly, especially no detailed description in the figure captions. We will give more detailed explanation in the revised version. As well known, at a long time scale, the water evaporated into atmosphere will be precipitated on land due to water cycle. In our manuscript, we defined the catchment network for water (vapor) transformation and transportation. To define the catchment network, we track the water using Lagrangian particle tracking method, i.e. the water precipitated into the first catchment is our study object and we marked it as P0; we focuses on the transportation and transformation of P0 and all the catchments that the water enters into was defined as the catchment network. For a special catchment of the catchment network, some precipitation comes from P0 and the other comes from other sources. In Figure 1, Catchments A2,j (j=1, 2, 3, . . .) represent the catchments that the evaporated water from Catchment 1 can reach; while Catchments A3,j (j=1, 2, 3, . . .) represent the catchments that the evaporated water from Catchments A2,j (j=1, 2, 3, . . .) can reach. Regarding the precipitation in Catchment 2 as the reviewer concerns, some comes from Catchment 1 and the other comes from other sources; however, according to the Lagrangian method, we only focus on the part from Catchment 1. Also, we can establish the balance equation of only the water from Catchment 1 for Catchment 2, P2 = E2 + R2, where P2 being the precipitation from Catchment 1, E2 and R2 being the evaporation and the runoff from the evaporation from Catchment 1, respectively. Figure 2 indicates the transportation and transformation of the water P1 according to the particle method. Accordingly, E2 doesn't represent all the evaporation from Catchment 2 but only the part originating from P1 (precipitated and evaporated from Catchment 1). Similarly, E3 only represents the part of evaporation originating from P1. For example, we assumes that P1 = 100 and only focuses on the transportation and transformation for the 100 water. P1 transforms into E1 = 60 and R1 = 40 in Catchment 1; then E1 possibly transforms into E2 = 36 and R2 =24 in Catchment 2. Regarding the water balance of Catchment 2, it is possible that the precipitation is 80 (including 60 from Catchment 1) and the evaporation is 48 (including 36 from E1). Regarding Figure 3, both of the potential of Points A and B (water in liquid) are zero, so we assume the two points directly connected. However, the potential difference between the two points equaling zero, which leads to no flux between the points. The objective of Section 2 is to obtain Equation (18), while that of Section 3 is to yield Equation (25). Then substitution of Equation (25) into Equation (18) leads to Equation (26).

Further remarks:

abstract: "homogeneity assumption" should be described more specific to the paper End of abstract, L15: There is no conclusion provided. Please explain what your results imply.

Response:

Thanks a lot. The homogeneity assumption indicated that the generalized flux has the same form for both water vapor transportation and chase transformation. The results may imply that the homogeneity needs further test or the Budyko hypothesis should be non-homogeneity. We will give more clear explanation in the revised version.

P5L2-5: it is unclear why this is mentioned here

Response:

In this paragraph, we wanted to give a brief review on the mathematical derivation for the Budyko hypothesis.

P6L18: Garrison 2017 not in bibliography

Response:

I am sorry for our carelessness and will add the reference in the revised version.

P8L10: φ(E0) = ; while φ = E/P on L27 ; unclear why the symbols is used for different meanings

Response:

It was caused by our carelessness. We will use the different symbols in the revised version.

P9L1: ". . . the MCY function is the best function among . . ." a) best in which respect and b) why is it the best?

Response:

Zhou et al. (2015) concludes "Based on the form and properties, Mezentsev-Choudhury-Yang's function is a better one among the existing Budyko functions to describe the water-energy balance in the two-dimensional state space (E0/P, E/P)" (Zhou, S., B. Yu, Y. Huang, and G. Wang (2015), The complementary relationship and generation of the Budyko functions,Geophys. Res. Lett., 42, 1781–

1790,doi:10.1002/2015GL063511). In this manuscript, we found only MCY equation satisfies Equation (18). Therefore we speculate that it is a best form. It is only a speculation. We will revise the expression in the revised version.

P14: There are two Zhou et al., 2015 indicate in the text to which you are referencing to

Response:

We will revise them in the revised version.

Figure 3 and in text: I recommend to use a different symbol for water vapor than P which is precipitation. It may be also useful to consider physical units of the quantities within the derivation.

Response:

Thanks a lot. We will use a different symbol and do more analysis on the physical units in the revised version.

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