"Natural laws of precipitation, great cycle, infiltration overland and groundwater runoff with a new formulas"

by A.Valjarević and D.Valjarević

Replay to Anonymous Referee #1

We would like to thank to anonymous reviewer for his time and effort in reading of our manuscript.
Below you can find replies to your comments. In particular, we used italic format to report all the questions raised by the reviewer and standard format to report our comments and responses.

There is not one references to any other scientific contribution (paper, chapter in books,...), even though a very limited list of references is given at the end of the paper.

Response: the reference list is maybe short, but that does not impact the quality of our work. Second and third references are the most important university textbooks of hydrology in our country, so you can not say that they are inadequate. Also, the references no. 6 and 7 are books of great importance.

The method is completely based on the six-component method of M.I.Ljvovic. To be honest, I have never heard of the method of Ljvovic, and a google search only resulted in websites referring to the HESSD paper which is under review.

Response: M.I. Ljvovic is famous Russian hydrologist and he defined a six-component method which is basic for calculating the coefficients of water balance. His books, where he has given the foundations of his method are

1. Ljvovič, M.I., Grin A.M, Drajer N.N.: Основъ Метода Изучения Водного Биланса и его Преобразованъй, Институт географии АН СССР Москва, 1963.
2. Ljvovič, M.I.: Вода и жизнь, Мъсль, Москва, 1986.

Also, in the book (which you can google search) Elements of physical hydrology by George M. Hornberger, Jeffrey P.Raffensperger, Patricia L. Wiberg, on the page 10 Ljvovic method is quoted.

The paper refers to the second sketch of M.Ljvovic (page 69, line 6), but as the paper makes no reference to that work it is impossible to assess to the statements that are made.

Response: Ljvovic's theoretical curves of water balance dependence on soil features (infiltration characteristic) (can be found in Ljvovič, M.I.: Вода и жизнь, Мъсль, Москва, 1986) is giving the same dependencies as in the

Fig.10. That are natural dependencies of water balance elements on infiltration characteristics for permeable terrains.

Basically, the paper is playing with the mass balance at the catchment scale which can be expressed as

$$\frac{\Delta B}{\Delta t} = P - S - U - E \tag{0.1}$$

Where B corresponds to the soil moisture storage. I presume (as I cannot check it) that the method of Ljvovic basically assumes that there is no change of water storage in the soil, or

$$0 = P - S - U - E \tag{0.2}$$

Response: Nowadays, in hydrology is using Ljvovic differential equations of water balance of the soil (it is the final formula of the Ljvovic method, which can be found in almost every book of hydrology) :

$$P = R + E; \quad R = S + E, \quad E = N + T, \quad P = (S + U) + (N + T),$$

$$K_u = \frac{U}{W}, \quad K_e = \frac{E}{W} = 1 - K_u.$$

These formulas were our start point, not the formula for catchment water balance (which describes the change of physical states of water) which you mentioned. The formula $0 = P - S - U - E$ was first developed by Ljvovic and from that our formula easily can be derived $P = S + U + E$.

Stating that this formula can be applied for whatever time period (page 71, line 13) is not correct, as for smaller time periods, the change in storage can be relatively large compared to the fluxes of P, S, U, or E.

Response: As a prove that this formula can be applied for any period of checking the water balance for the whole Earth.
Data from the book Elements of physical hydrology are $P = 800mm, E = 490mm$ and by formula for evaporation coefficient $\frac{E}{P} = 0.61$. That value is greater then $0,25$ which means that terrain is impermeable. By new formula (from this work) $W = \sqrt{PE}, W = \sqrt{800 \cdot 490} = 626$. By Ljvovic method $W = P - S \Longrightarrow S = P - W \Longrightarrow S = 800 - 626 = 174$. Also, $P = S + U + E \Longrightarrow 800 = 174 + U + 490 \Longrightarrow -U = -800 + 174 + 490 \Longrightarrow -U = -136 \Longrightarrow U = 136mm$. Then, $S + U = R$ (Ljvovic method), $R = 174 + 136 = 310mm$, and by Elements of physical hydrology by George M. Hornberger, Jeffrey P.Raffensperger, Patricia L. Wiberg, on the page 10 where it is stated that the water quantities for all the land areas of the world is $R = 310mm$. With new method in two steps can be calculated water quantities, knowing only

two parameters evaporation and precipitation, instead of using complicated differential equations.
The well known definition of climate says that climate is regime of weather types for at least one year. So, it is little frivolous to do any serious study for determination coefficients of water balance in shorter period. Anyway, our method can be applied and in shorter period, only problem is that in winter time it is impossible to determine a coefficient of evaporation because of sublimation (ice).

The paper discerns between impermeable and permeable terrains. Unfortunately, the definition that is given to impermeable is different from the one that is widely accepted (i.e. impermeable= no water can infiltrate). In the paper impermeable refers to a terrain which has the following property: if infiltration increases , then the evaporation increases.
A permeable soil (i.e. a soil in which water can infiltrate) is defined as a soil which has the following property: if infiltration increases, then the recharge to the groundwater runoff increases.

Response: We didn't give the definitions of impermeable and permeable terrains, because that definitions are widely known and there is no need to mention them. Those definitions can be given and by capillarity of water (Book of hydrogeology, for impermeable terrains is $> 0,25mm$ (no capillarity), and for permeable terrains is $< 0,25mm$ (groundwater motion is possible under force of gravitation) not only the way you mentioned. We used the properties of those terrains, as you already stated, which are logical, mathematically based and confirmed by practical measurements.
To be more specific, in impermeable terrains, with increase of infiltration characteristics, impermeability also increases, but with different intensity. Evaporation increases slowly to 0,5 of infiltration characteristics, and after that, suddenly, becoming equal to infiltration, near maximum value of infiltration characteristics. Beside text, the dependencies are shown in a Figure 9. For permeable terrains we gave the dependencies on page 69, line 9.

The assumption that $\frac{W^2}{PE} = 1$ is physically meaningless for so-called impermeable terrains.

Response: Not true. All coefficients K_w, K_e, K_u, K_s are in some reciprocal dependence and as appropriate coefficients are complemental up to 1 and they are located within standardized coordinate system. If we divide K_w with K_e we get innumerable group of lines $\frac{W^2}{PE}$ which intersect $K_w K_e$ curves in different points. Intersection only one of them with corresponding curve gives point of catchment area as a result. On the diagonal d_2 (d_2 is positioned as on the Fig.7) $\frac{E}{P}$ coefficient increases upward, and $\frac{R}{P}$ increases downward.

So, only on diagonal d_2 is valid $\frac{E}{P} + \frac{R}{P} = 1$. Therefore, on no one else line but diagonal d_2 is established harmony among all water balance coefficients, causing their changes when only one becomes different. By this can be concluded that the point corresponding to the catchment area is located in the intersection $K_w K_e$ (that is $\frac{E}{P}$) curve and diagonal d_2. On the diagonal d_2 is valid $K_w = K_e$ and $K_s = K_u$. So, for impermeable terrains is valid $\frac{W^2}{PE} = 1$. It is mathematically correct, for impermeable terrains the total rainfall must evaporate in some shape. The fact you mentioned that 10% of infiltrated water is used by plants is not subject of this work. Assumption $\frac{W^2}{PE} = 1$ is logical, can be mathematically proved and physically is correct.

In equation on line 22 is stated that

$$K_e = 1 - K_w.$$

In fact, $K_e = 1 - K_u$*, so what is assumed (and this is also stated in line 8 of page 66) is that* $K_w = K_u$*. Again, this assumption has no hydrological meaning for so-called permeable terrains.*

Response: Again, not true. In the permeable terrains point of the watershed is also in diagonal d_1, because only in the line, all water balance coefficients are included in the 0-1 range. It is obvious that the $K_w K_e$ curve is known, that is $\frac{E}{P}$, intersecting the diagonal d_1 in two parts (see Figure 7). We also stated that in each point of the d_1 diagonal is valid $K_w + K_e = 1$ (see again Fig. 7). The catchment area point for permeable terrains is located in an intersection of d_1 diagonal and $K_w K_u$ curve ($\frac{U}{P}$), which is unknown value. So, we consider the intersections of curve $K_w K_e = \frac{E}{P}$ (with known value and because that point is intersection of the diagonal d_1 and curves $K_w K_u$ and $K_w K_e$, see Fig.7) with diagonal d_1, so the equality $K_w + K_e = 1$ must be satisfied for those points. Again, the subject of this work was not deployment of infiltrated water, but explanation of circulation of water as well as exact determination of coefficients of water balance.

The equations in line 22 of page 64 and the K_w *values as given in the equation on line 5 of page 65 are based on a physically meaningless assumption.*

Response: The equations on the pages 64 and 65 are logical continuation of the equation $K_w + K_e = 1$, mathematically proved and physically correct.

And on the end, the one who is not introduced with the work of Ljvovic, especially those who have never heard of that great hydrologist, can not comment, because are not informed about the theory which Ljvovic developed, especially if they recall the internet references which are not always valid. In this case the theory was confirmed by practical research (which is more important) and using mathematical tools. So, most comments are superfluous and unnecessary. At the end, with all respect we think that the last comment is very acute and exaggerated.