

## **Interactive comment on “A simple water-energy balance framework to predict the sensitivity of streamflow to climate change” by M. Renner et al.**

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We thank referee III for his review. His view is in agreement with our understanding of the methods shown in our manuscript.

He further asks for more empirical evidence of the validity of the CCUW hypothesis. In this manuscript we present the methodology and compare it with approaches using the Budyko hypothesis. In addition we provide three case studies using published data. Further, please note, that there is another paper, (Renner and Bernhofer, 2011), where we apply the CCUW hypothesis to a large data set comprising more than 400 stations in the continental US.

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Still we agree with Referee III, that more investigations are useful, and invite everyone to check the validity of CCUW hypothesis using more data sets.

### **Minor comments:**

**1. P.8804, line 20, I suggest more accurate expression. The formula proposed by Pike (1964) is  $E = \overline{E}p * P / (E\overline{p}^2 + P^2)^{1/2}$ , with  $E\overline{p}$  being Penman equation. Mezentsev (1955) derived the formula  $E = \overline{E}p * P / (E\overline{p}^n + P^n)^{1/n}$  in mathematics. Choudhury introduced an adjustable parameter into Pike equation and replaced  $E\overline{p}$  with net radiation  $Rn$ ,  $E = Rn * P / (Rn^n + P^n)^{1/n}$ . Yang et al. (2008) analytically derived the equation  $E = \overline{E}p * P / (E\overline{p}^n + P^n)^{1/n}$ .**

We will take care of these suggestions and also add the reference to (Yang et al., 2008).

**2. P.8828, Fig.6, the elasticity of runoff to precipitation has a very large slope when CE = 1.3 or 1.2. This is very different from the elasticity from the Budyko hypothesis. If the causes (situations in real world) can be explained in physical, it will show the hypothesis a better theoretical frame than the Budyko hypothesis.**

A theoretical explanation of the large sensitivity coefficients can be found from the general definition of elasticity of runoff  $Q$  to precipitation  $P$  (Schaake, 1990):

$$\varepsilon_{Q,P} = \frac{P}{Q} \left( \frac{\partial Q}{\partial P} \right). \quad (1)$$

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Thus, the elasticity coefficient is primarily dependent on the inverse of the runoff ratio  $P/Q$ . Looking at the elasticity coefficient derived from the CCUW hypothesis (bracketed term in eq. (21))  $\varepsilon_{Q,P} = \frac{P}{Q} - \frac{(P-Q)E_p}{Q(E_p+P)}$ , we see that this dependency is being kept. So the larger the inverse of the runoff ratio, the larger the sensitivity. To get back to figure 6, this means that at aridity index greater than 2 and a value of  $CE > 1.2$ ,  $E_T/P$  will be very small and thus  $P/Q$  very large, such that the resulting  $\varepsilon_{Q,P}$  will be large. Or phrased differently, if runoff is very small compared to precipitation, a relative change in precipitation will have large (relative) consequences on runoff.

In contrast, the sensitivity of streamflow to changes in climate derived from the Budyko hypothesis shows that there is an upper bound of the sensitivity coefficients, cf. Figure 6 right panel. This is because of the substitution of  $Q$  in the bracketed term of equation (25) with the respective Budyko curve function. By doing this, the water limit will be approached asymptotically, however, at the cost of neglecting the dependency to the inverse of the runoff ratio.

Furthermore, the graph in Figure 6 shows, that  $\varepsilon_{Q,P}$  tends to infinity, when aridity increases for a specific value of  $CE$ . Thus, values of  $CE$  larger than one are limited to certain aridity domains.

Best Regards,

Maik Renner (in the name of my co-authors)

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## References

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