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Hydrology and Earth System Sciences Discussions

Interactive comment on "On the importance of including vegetation dynamics in Budyko's hydrological model" *by* R. J. Donohue et al.

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General comments. This manuscript reviews some of the limitations of the Budyko framework and repeatedly states that vegetation attributes and dynamics should or could be incorporated in the framework in order to extend its applicability to smaller/shorter spatiotemporal scales than those it was designed for. The manuscript is disappointing by only making such statements without proposing any concrete approach for incorporating vegetation attributes and dynamics in the Budyko framework or testing the applicability of such a revised Budyko framework. As a review of Budyko's framework the present manuscript is incomplete and does not contribute new insights or new explanations for deviations from the Budyko curve other than those already discussed in previous publications (e.g., Eagleson, 1978; Hsuen-Chun, 1988; Milly, 1994; Zhang et al., 1999; Choudhury, 1999; Dooge et al., 1999; Zhang et al., 2001; Sankara-

subramanian and Vogel, 2002; Zhang et al., 2002; Rodríguez-Iturbe and Porporato, 2004; Zhang et al., 2004; Potter et al., 2005).

1. Objectives. The authors wish to revisit the Budyko framework and to highlight the sometimes-forgotten assumptions within it. However, no reasons are given for the need to revisit the Budyko framework nor any references are made to published work in which the underlying assumptions of the Budyko framework were actually stretched too far or misinterpreted. We are not aware of any publication in which Budyko's curve was used without pointing out the limitation of the framework. On the contrary a good body of literature exists (Eagleson, 1978; Milly, 1994; Eagleson, 2002; Rodríguez-Iturbe y Porporato, 2004; Zhang et al., 2004; Potter et al., 2005, among others) in which those limitations have been discussed and attempts have been made to explain the deviations from the Budyko curve. Within that context the purpose of the present manuscript is poorly defined. What will it contribute to the existing literature?

2.1. Catchment water and energy balances. What is the added value of using kilograms and seconds when outlining the Budyko curve? The authors consider changes in Sw as a function of changes in the volume of the bucket and the mass concentration within the bucket, but do not apply a similar level of interest in describing the other term in the water balance. One could argue that temporal variation in the volume of the bucket would imply changes in E and Q as well (Laio et al., 2003; Rodríguez-Iturbe and Porporato, 2004).

2.2. The framework and curve. Why not write Rn in mm equivalent and get rid of lambda;, which is a constant?

Budyko's equation of relationship (Eq. 11) is actually the geometric mean of the equations proposed by Schreiber (1904) and Ol'dekop (1911). This origin should be mentioned as such. What is more, these two references should have been included in this introduction to the Budyko curve.

The authors interpret Budyko's statement (p. 6, fore last paragraph) as: the larger the

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catchment area Ac, the more Rn behaves as a macro-climatic variable. A more correct interpretation seems to be: the larger Ac the better Rn defines the energy limitation for evapotranspiration.

3.1. Previous studies. Similar overviews have been made before (Zhang et al., 1999; Zhang et al., 2004). This section does not add anything new to the literature.

3.2. Interactions between analysis scale, vegetation and Budyko deviations.

The authors (p. 10 first lines) implicitly suggest that there are other researchers who have tried to address “important ecological and hydrological issues” with the Budyko framework while “omitting measures of vegetation”. Why would this be attempted when the Budyko framework was clearly designed to address long/wide scale hydrological-climatological relationships?

Page 10, 3rd paragraph: Integration of “vegetation” [this is very vague!] into the Budyko framework is expected to increase its reliability in predicting E and Q when Ac is small and render it more useful at typical management scales. This statement requires further development and underpinning.

Page 11, fore last paragraph: this is a repetition of statements that have been made (several times) earlier on in the manuscript.

4.1. Three key vegetation attributes. The importance of L, Ag and Zr, for plant water relations are well established. By outlining some key relationships the authors suggest that they will propose an approach for integrating these vegetation attributes in the Budyko framework, but finally they do not develop the subject any further at all.

4.2. Seasonal vegetation dynamics. We do not see the advantage of introducing the term “raingreen”, when it is perfectly clear that seasonal dynamics of deciduous perennials and annual plants in environments with strong wet/humid seasonal contrasts are strongly related to precipitation. Equally, the other way around, we know that if there is a strong seasonality in the response of the vegetation in such wet/dry environments it

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is probably caused by deciduous perennial and annual plants.

Page 15, first paragraph: The authors suggest that “some indication of the relative contributions of raingreen and evergreen vegetation types in a catchment’s water balance will most likely explain more of the vertical deviations that occur around the Budyko curve”. No attempt is made to test this hypothesis, while the introduction suggests that this is one of the objectives of the paper.

4.3. Annual vegetation dynamics. Page 15, last paragraph: authors state that evergreen Ag $>$ raingreen Ag, but provide no refs. Photosynthetic capacity of annuals and deciduous trees can be quite similar or higher than that of evergreens (e.g. p. 94 Larcher (1980) Physiological plant ecology. Springer-Verlag).

4.4. Summary. This summary (why include a summary here at all?) states what has been stated repeatedly in the paper, namely that it is important to incorporate vegetation dynamics in the Budyko framework. We have nearly reached the end of the paper and no attempt has been made yet to demonstrate how those vegetation dynamics could be incorporated!

5.1. Ecohydrological equilibrium. This section does not capture the key developments in the field of ecohydrology, omitting for example the seminal work of Peter Eagleson (1970s). Statements about L being a reliable predictor of zr and Ag may be true (where are the references?) but are subject to the same limitations as the Budyko framework: applicable at long/wide scales.

5.2. Remotely-sensed measures of leaf area index. The subject of this section is a research field in its own right. The authors highlight some relationships between NDVI and vegetation attributes, but omit much of the literature on the remote sensing of leaf area index (see, for example work by MODIS science team) or the problems associated with the NDVI (e.g. saturation at full cover, soil background effect). Again the authors suggest including some sort of information (i.e. here remotely-sensed LAI) in the Budyko framework without making any attempts to show how this may be

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achieved and/or demonstrate its usefulness.

6. Conclusion. Page 19, 2nd and 3rd paragraphs: repetition of previous statements, but no development of the subject. See start of 3rd paragraph: “As far as we are aware, this proposal has not yet been tested”. We expected the present ms to propose an approach for improvement/modification of the Budyko framework, to test it and to report on the results. The manuscript is disappointing.

Reviewers recommendation: Rewrite the paper either as a much more complete literature review (see suggested refs below) or shorten the review and statements strongly and add, for example, a case study in which it can be shown that including vegetation attributes actually improves the Budyko framework or extends its applicability to new spatiotemporal scales.

References. Arora, V.K. 2002b. The use of the aridity index to asses climate change effect on annual runoff. Journal of Hydrology, 265, 164-177. Choudhury, B.J. 1999. Evaluation of an empirical equation for annual evaporation using field observations and results from a biophysical model. Journal of Hydrology, 216: 99-110. Dooge, J.C.I., Bruen, M., Parmentier, B. 1999. A simple model for estimating the sensitivity of runoff to long-term changes in precipitation without a change in vegetation. Advances in Water Resources, 23: 153-163. Eagleson, P.S. 1978d. Climate, soil, and vegetation. 4. The expected value of annual evapotranspiration. Water Resources Research, 14(5): 731-739. Eagleson, P.S. 2002. Ecohydrology: Darwinian expression of forest form and function. Cambridge University Press, Cambridge. Hsuen-Chun, Y. 1988. A composite method for estimate annual actual evapotranspiration. Hydrological Sciences Journal, 33: 345-356. Laio, F., Porporato, A., Ridolfi, L., Rodriguez-Iturbe, I. 2001. Plant in water-controlled ecosystems: active role in hydrologic processes and response to water stress. II. Probabilistic soil moisture dynamics. Advances in Water Resources, 24: 707-723 Milly, P.C.D. 1994. Climate, soil water storage, and the average annual water balance. Water Resources Research, 30: 2143-2156. Ol’dekop, E.M. 1911. On evaporation from the surface of river basins. Transactions on Meteoro-

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logical Observations. Lur-evskogo, Univ. of Tartu 4, Tartu, Estonia. Potter, N.J., Zhang, L., Milly, P.C.D., McMahon, T.A., Jakeman, A.J. 2005. Effects of rainfall seasonality and soil moisture capacity on mean annual water balance for Australian catchments. Water Resources Research, 41, W06007, doi:10.1029/2004WR003697. Rodríguez-Iturbe, I., Porporato, A. 2004. Ecohydrology of water-controlled ecosystems: soil moisture and plant dynamics. Cambridge University Press, Cambridge. Sankarasubramanian, A., Vogel, R.M. 2002. Annual hydroclimatology of the United States. Water Resources Research, 38(6), doi:10.1029/2001WR000619. Schreiber, P. 1904. Über die Beziehungen zwischen dem Niederschlag und der Wasserführung der Flusse in Mitteleuropa. Meteorol. Z., 21: 441-452. Zhang, L., Dawes, W.R., Walker, G.R. 1999. Predicting the effect of vegetation changes on catchment average water balance. Technical Report 99/12, Cooperative Research Centre for Catchment Hydrology, Canberra, ACT. Zhang, L., Dawes, W.R., Walker, G.R. 2001. Response of mean annual evapotranspiration to vegetation changes at catchment scale. Water Resources Research, 37: 701-708. Zhang, L., Hickel, K., Dawes, W.R., Chiew, F.H.S., Western, A.W., Briggs, P.R. 2004. A rational function approach for estimating mean annual evapotranspiration. Water Resources Research, 40, W02502, doi:10.1029/2003WR002710.

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