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Hydrology and Earth System Sciences Discussions

Interactive comment on "Neural network emulation of a rainfall-runoff model" *by* R. J. Abrahart and L. M. See

Anonymous Referee #1

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The core of this paper is very interesting contributing to the on-going debate about the acceptance of the use of neural networks in hydrological modelling. In this paper, the multi-layer feed forward neural network (MLFFNN) was trained to simulate the runoff generated from a simplified non-linear equation used originally in the water balance module of a conceptual rainfall-runoff model known as the Xinanjiang model. The variables controlling the equation are used as inputs to the MLFFNN. A linear multi-input-single output model was also developed. This linear model uses the same inputs as the MLFFNN. Four numerical experiments are carried out to illustrate the powerful capabilities in modelling noise-free non-linear hydrological relations.

In general the paper is well written and it was easy to follow. The results are also very well presented. However, this reviewer felt that the rationale behind the Xinanjiang model equation used in this paper is not very well explained. This may help in better understanding and interpretation of the results. Also, this reviewer is not sure whether there is a need for four numerical experiments. There is some duplication between three of these experiments. In fact, the experiments could be reduced to two if the non-linear equation is expressed in a non-dimensional form. The limits of the parameter b controlling the spatial variability used in the paper may not be enough to capture the complex non-linearity of the equation of the Xinanjiang model used in the study.

The following are comments explaining in more details the points which are raised above.

Emulation of the Xinanjiang model

1) In principle, the main idea behind this model is that the catchment is conceptualised as consisting of a population of storage elements with different field storage capacity values. The field capacity is assumed to vary spatially and this variation can be described by a probability distribution function F(S) providing the fraction of the catchments area with storage having field storage capacity values less than or equal to S. The Xinanjiang model normally uses the Pareto distribution probability distribution function according to:

$$F(S) = 1 - \left[1 - \frac{S}{S_{max}}\right]^b \quad \text{for} \quad 0 \leq S \leq S_{max}$$

where b is the shape parameter controlling the spatial variability and S_{max} is the maximum value of storage field of the storage capacity.

From the above figure it can be seen that the shape of F(S) changes (i.e. concaves upward) when the value of b exceeds 1. There are special cases when b=0 (constant storage), b=1 (uniform distribution) and b=∞ (constant storage). The figure shows that parameter b has a great role on controlling the shape of the distribution function. In the numerical experiments conducted in the study the parameter b is allowed to vary

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between 0.1 and 0.5. Thus, this range may not be sufficient to capture the whole non-linearity of the equation of the Xinanjiang model as it this range does not include the special limiting cases as well as the cases where the curvature of the curves changes direction. The reviewer is not sure about the likely impacts of including this. It may well not change the substantive conclusions of the paper.

2) Equation (1) can be expressed in a non-dimensional form by diving by W_m as

$$\frac{R}{W_m} = \frac{P}{W_m} - \left(1 - \frac{W_0}{W_m}\right) + \left[\left(1 - \frac{W_0}{W_M}\right)^{\frac{1}{b+1}} - \frac{P}{(1+b)W_m}\right]^{1+b}$$

Defining $C_1 = \frac{P}{W_m}$ and $C_1 = \frac{W_0}{W_m}$ the previous equation can be expressed as;

$$r = \frac{R}{W_m} = C_1 + C_2 - 1 + \left[(1 - C_2)^{\frac{1}{b+1}} - \frac{C_1}{1+b}\right]^{b+1}$$

where r is the standardized runoff. Given that the generated values of C_1 and $C_2 \leq 1$ then the generated values would likewise be less than 1. If the above non-dimensional equation is used instead of equation (1), then the external input array to the network will consist of a selection from C_1, C_2 and b. The use of the above equation has two main advantages 1) There may be no need to rescale the external inputs (C_1 & C_2) and the output 2) It makes the results of the different experiments more comparable as there is no need to use different units [sdu & sru] for the runoff when plotting the graphs of the MLFFNN estimated runoff against those produce by the Xinanjiang model. Furthermore, using the above non-dimensional form would reduce the number of experiments from four to two. In the first experiment, the external would consist of C_1, C_2 and b while in the second one the external inputs would consist of C_1 and C_2 as used in the fourth experiments.

3) The author need to make it more explicit of their rationale behind constraining the ratio $C_1 + \frac{P}{W_m}$ to be less than or equal to one.

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Results

- It may be of a great help if the runoff is standardized by dividing by Wm instead of P. This may make the interpretation of results more easier. The paper would greatly benefit if figure 10 is discussed before discussing the results of individual numerical experiments. This figure holds the key for interpreting the results. The authors may include the below discussion or a similar one which would help the reader to fully understand the results

  “Figure (10) can be split diagonally into different part. The first part has a rough surface with a lot of speckled patterns while the second has a smooth well defined surface. the second in the second part of the figure. This split is not surprising and in fact is the results of equation (2) and (3). The first part is produced by equation (3) which is a complex non-linear multi-value function. However, when the effective precipitation is sufficient to augment the storage deficit the parameter b is eliminated from the picture and the standardized runoff r is basically a linear function of C_1 and C_2. This would a results in a smooth linear surface which corresponds the second part of the diagram”

- The trends in the results of experiments 2, 3 and 4 whether obtained using the MLFFNN or the linear model are quite similar. This is not surprising as these experiments use the same information content albeit in different forms. Figures (2) to (8) show two distinct runoff response regions. My interpretation of the results is that the upper part of the would correspond the smooth surface and the lower part would corresponds the region of the speckled patterns. Thus, experiments two and three can be removed without loosing too much of the generality of the results.

- The authors should justify removing the parameter b from the external input array in experiments 2 to 4 as opposed to removing W_0 or W_m.

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Minor Comments:

- It worth noting that the Probability-Distributed Storage Capacity developed at the Centre of Ecology and Hydrology is also based on the Xinanjiang model (see Moore; 1985, 1992, 1993 and Senbeta et al., 1999)
- The authors should exercise caution when using the term semi-distributed in conjunction with the Xinanjiang model. This model is a probability distributed model which can be applied in a semi-distributed when the catchment is subdivided into a number sub-catchments and the model is applied to these sub-catchments using different parameter sets and/or input information.
- To be more precise the term precipitation should be change to effective precipitation throughout the paper.
- Delete equation (4) as it is a special limiting case of equation 2.
- The authors need to mention the type the neuron transfer function used in their neural network model.

References

Moore, R.J., 1985. The probability-distributed principle and runoff production at point and basin scales. Hydro. Sci. J., 30(2), 273-297.

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Senbeta, D.A., Shamseldin, A.Y. & O'Connor, K.M. (1999). Modification of the probability-distributed interacting storage capacity model. Journal of Hydrology, vol. 224, 149-168.

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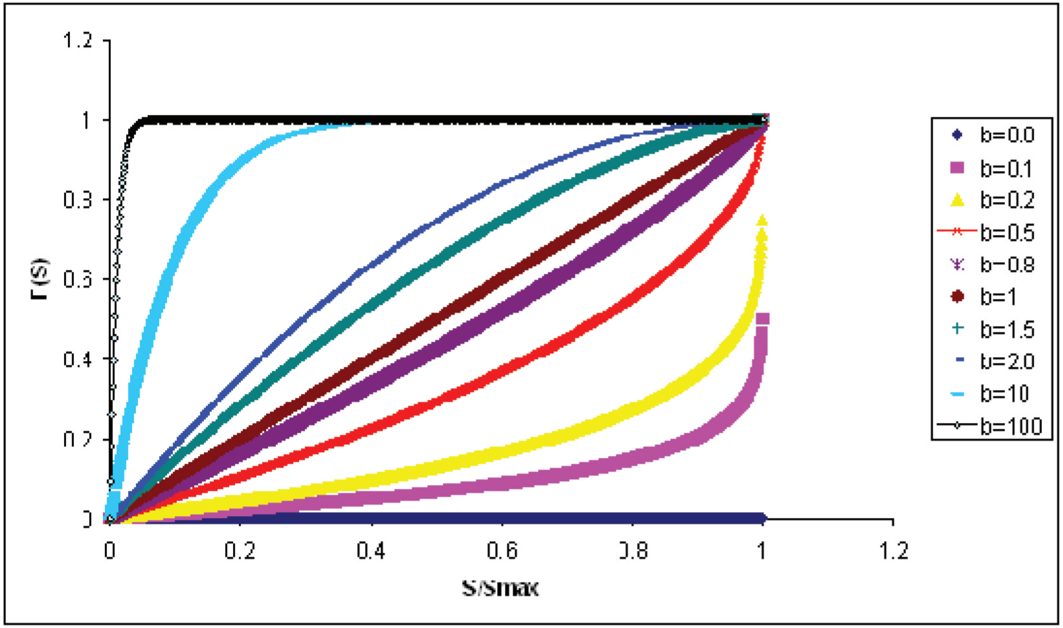

Figure 1: The figure highlights the variation of F(S) with different values of b.

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