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Hydrology and Earth System Sciences
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Discussions

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Interactive Comment

Interactive comment on "Testing the realism of a topography driven model (FLEX-Topo) in the nested catchments of the Upper Heihe, China" *by* H. Gao et al.

H. Gao et al.

h.gao-1@tudelft.nl

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Dear Referee1:

We would like to thank the first referee for his/her thoughtful and constructive comments and detailed reading of the manuscript. Regarding the questions raised by the referee, we would like to explain our view in detail for each question:

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Review comments: 1) The title of the manuscript states that model realism is tested in this manuscript. I doubt if one can say that a conceptual bucket model is realistic anyway. To avoid this discussion I would advice to change the word 'realism' into 'transferability': not only in the title but throughout the manuscript.

Answer: The referee is right that conceptual models are simplifications of reality, but this is true for all hydrological models, even for those claiming to be physically based. However, conceptual models do obey the water balance of different runoff generating processes, and if well designed, these mechanisms reflect realistic time scales and available storage. By designing suitable model configurations that are in line with the modeler's perception of the system and that allow for sufficient process heterogeneity, the realism of a conceptual model can be increased. This manuscript deals with "testing the realism", meaning that it investigates to what degree a realistic representation has been achieved, but we do not intend to claim that the model is "realistic" in absolute terms. In the revised paper, we shall include a paragraph explaining this point of view and we shall make clear that we do not make unjustified claims of "realism".

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Review comments: 2) I have some problems with the large amount of parameters of the FLEX^T model; especially with respect to the other two models. Looking at it from a distance, one may argue that the better performance is simply due to the increased complexity. The authors have to make clear that the better transferability of FLEX^T is not due to the increased complexity, but due to the explicit incorporation of the dominant runoff processes of each landscape attribute and, more important, due to the fact that the areal fractions of each sub model can be obtained a priori and thus adapted for different (sub) catchments. A proper way to show this is to compare FLEX^T with a similarly complex model. One can think of the same model as FLEX^T, but with the areal fractions treated as calibration parameters, or a similar model as FLEX^D, but now with all parameters of the parallel model being calibrated independently. I still think that the FLEX^T model will perform the best, but the comparison will be a fairer one.

Answer: It is a valid question whether it is the increased complexity or the model struc-

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ture that made $FLEX^T$ perform better in transferability. We appreciate very much that the reviewer suggested two methods to demonstrate that $FFLEX^T$ performs better because of model structure instead of merely because of higher complexity. From these two methods, we prefer the second one, which compares $FLEX^T$ with a similarly complex or even more complex model. The first method could be better tested in small catchments, where spatial precipitation and temperature patterns are likely less pronounced than in the large study catchment. Our colleague, Shervan Gharari, did test this hypothesis in Luxembourg, which is now open for discussion on HESSD (Gharari et al. 2013a,b). In our case study, due to the large number of distinct modelling units (7 elevation zones, 4 Thiessen polygons, and 4 landscapes), there are too many free parameters if we treat the areal fractions as calibration parameters. This makes this method difficult to apply. We therefore used the second method to show that the better performance of $FLEX^T$ is not caused by more complexity, but due to a better model structure which explicitly incorporates different dominant hydrological processes in different landscapes. In order to demonstrate this, we allowed different parameters sets for different Thiessen polygons in $FLEX^T$. This resulted in a model with 42 free parameters ($FLEX^{D1}$), which is nearly twice the amount of parameters in $FLEX^T$ (23 free parameters). The results of the these model comparison are shown in the Appendix (Table1, Fig.1 2). These results show that the more complex model ($FLEX^{D1}$) performs as good as $FLEX^T$ or even better in calibration and validation. But its performance did not improve in transferability, since it did not take landscape classifications into account.

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Comments: Introduction: Keep in mind that at this stage of the manuscript, the fact that topography offers important information is still a hypothesis. Phrasings such as 'but they fail to extract additional information from topography' (P66, L4-5) or 'it is important to investigate a more efficient use of topographic data' (P66, L16-17) may be too strong.

Answer: Agreed. We shall make the suggested change to this paragraph.

Comments: P67, L28: Make clear that you refer to transferability of both model structure AND model parameters.

Answer: The term "transferability" means both model structure and model parameters. We shall make this clear in the revised manuscript.

Comment: P71, L22: Why using percentages for C_p and not just a lapse rate in m^{-1}? Same for C_t. Then you lose the factor 10000 and 100 in Eq. (1) and (2).

Answer: You are completely right. We shall use a lapse rate m^{-1} for both.

Comment: P72: L2: the unit used for the precipitation lapse rate is not the same as for C_p: $mm(100ma)^{-1}$ vs. $\%(100m)^{-1}$

Answer: The reason for this is that literature values in China are available for equation 1, and because annual precipitation is never zero, this method applied. However for daily precipitation, zero precipitation can occur which makes equation 2 necessary. For annual precipitation the equation used is:

$$P_j = P + (h_j - h_0)C_{pa} \tag{1}$$

But for daily precipitation we used:

$$P_j = P(1 + (h_j - h_0)C_p) \tag{2}$$

So the mm/(m a) is suitable for annual precipitation, but not suitable for daily precipitation, because there are lots of days without precipitation within one year. We shall add the annual lapse rate equation (1) in the final version.

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Comment: P72, L4-5: why are the lapse rates for the different stations different? Which data is used to derive these?

Answer: The annual lapse rate C_{pa} is the same for all four precipitation stations. However this unit is only suitable for annual precipitation interpolation, but not for daily precipitation, as we mentioned above. To derive C_p for each Thiessen polygon, we need to take the annual stationary precipitation and elevation into account. In this case, the different Thiessen polygons have different precipitation increase gradients, due to the difference in observed precipitation. Because the base stations are different, the lapse rates are different as well.

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Comment: Section 4: add also the mass balance equation for all reservoirs: not only the flux Equations

Answer: We added the mass balance equations for all reservoirs. And we made a table of equations, which includes all the mass balance equations and closure relations together. We hope this will make the description clearer and more concise.

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Comment: Section 4.1: Please clarify why this model structure is chosen. Is it linked to the perceptual model (and how) or is it a completely arbitrary model structure?

Answer: The model structure is not chosen arbitrarily. It is linked to our perceptual model, which we developed step by step. This will be made explicit in the text how it is linked to the perceptual model.

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Comment: Eq. (4): Why is I_{max} introduced? To me it seems exactly the same as $S_i/n\delta t$?

Answer: I_{max} is the maximum daily interception storage. As long as the storage is below this threshold, all precipitation is intercepted and runoff is not generated.

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Comment: P75, Eq. (9-10): This lag function means that the oldest day $(t - T_{lag})$ contributes the most, while there is no tail. This seems rather strange to me (unless my perception of the runoff processes is completely wrong).

Answer: The lag function represents the distribution function of the travel time of instantaneous precipitation to the outlet, much like is done in the rational method, where Tlag represents the time of concentration when the entire catchment contributes to runoff. It is essentially used for the rising limb of the hydrograph. The tail, the recession, is dominated by the two response reservoirs (S_f and S_s), which represent the fast recession and the groundwater recession processes as previously shown by Fenicia et al. (2007) and Kavetski and Fenicia (2011). Your point would be valid if we have used rising limb distribution without any reservoir afterward.

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Comment: P86, L5: The fact that the relative proportion of each landscape can be determined a priori is, in my opinion, a very important reason to successfully transfer the model to the sub catchment. I suggest emphasizing that.

Answer: Good suggestion. Thank you.

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Comment: Section 5.2: This section seems a bit suggestive to me. It is correct (and indeed intriguing) that the landscape classification correspond so well with the land cover map. But the statement that it clearly illustrates that topography is an integrated indicator of energy and water availability and redistribution of natural vegetation cover's growing and evolving environment is a bit too strong. For example: the fact that South facing slopes receive (in the Northern hemisphere) more solar radiation than the North facing slopes and thus have higher potential evaporation rates is also correct, but this

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thus not necessarily mean that the dominant runoff processes are different: it is merely a hypothesis that can be tested.

Answer: Thank you for your comments. The conclusion could be too strong, and we will change these statements. To clarify, on hillslopes, the topography influences the natural land cover. Correspondingly, this influences the interception and the maximum storage in the root zone. Admittedly, the hydrological processes on grassland and forest covered hillslopes are almost the same but with different parameters. Therefore we used the same model structure to simulate their hydrological processes. But the hydrological processes on bare soil/rock hillslope and wetland/terrace are different from the hillslopes.

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Comment: P90, L29: I agree that soft data (may) have added value, but the shown results do not demonstrate it. To do that, the results of the ($FLEX^T$) model should be compared with the same model, but then calibrated without constraints.

Answer: We did this comparison for the revised version of the manuscript, and posted our results in the Appendix below (Table 7, Figure 8, 9). The conclusion is that both the model structure and the constrained calibration method improved the transferability. With a better model structure, even without constraint ($FLEX^{T0}$), we can get better simulation results. With the constrained parameter calibration ($FLEX^T$), the soft data is really helpful for us to get better transferability. In our point of view, the parameter constraint is part of the $FLEX^T$ modelling approach. It is an approach that allows to make use of hydrological knowledge, such as topographic and land cover information into our model. The model structure and the soft data represents the knowledge we have. Both the model structure and soft data matter.

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Minor comments

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P64, L3: remove ’poorly understood’

Answer:

We shall make this correction in the final version.

——————————————-

P64, L9: should be: spatially variable input

Answer:

We shall make this correction in the final version.

——————————————-

P66, L3: add potential before additional information

Answer:

We shall make this correction in the final version.

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P66, L22: replace ’(Savenije 2010)’ with ’and the subject of this study’

Answer:

We shall make this correction in the final version.

——————————————-

P66, L25: remove comma after ’is’

Answer:

We shall make this correction in the final version.

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P66, L27: Remove reference to Gharari et al. 2011. This is already referred to in the

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line above.

Answer:

We shall make this correction in the final version.

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P68, L7: The catchment is not controlled by the gauging station. At the gauging station, the catchments has an area of X m2.

Answer:

We will change the word from "controlled" to "gauged".

——————————————-

P68, L22-23: List these references in chronological order? You may want to do that throughout the manuscript.

Answer:

We shall make this correction in the final version.

——————————————-

P69, L4-5: replace ’and can help’ with ’which we used’

Answer:

We shall make this correction in the final version.

——————————————-

P69, L6-7: did Beven (2012) and Tetzlaff et al. (2012) identify the different landscape classes used in this study? If yes, please rephrase to make this clear.

Answer: Beven (2012) highlighted the hydrological modelling procedure. In his book, he mentioned the modelling procedure from perceptual model to hydrological model,

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making use of the understanding of catchment behavior, which is the same as we did in this manuscript. We deleted the citation to Tetzlaff et al. (2012).

——————————-

P69, L28: is SSF not a preferential flow?

Answer:

SSF may be preferential flow. It could, depending on the catchment and the respective conceptualization however for example also be interpreted as matrix flow in a higher permeability layer of the soil. We changed the description correspondingly.

——————————-

P70, L7: remove reference to Savenije 2010.

Answer:

We shall make this correction in the final version.

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P70, L9-12: Please rephrase this sentence.

Answer:

We shall make this correction in the final version.

——————————-

P71, L14: Is there a reason why seven elevation zones are chosen?

Answer:

Since the elevation ranges between 1673m and 5000m, which can divide 7 elevation zones with 500m interval.

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P71, L21: remove ’stationary’, add unit for P, replace ’interpolated’ with ’extrapolated’

Answer:

We shall make this correction in the final version.

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P71, L23: add unit for temperature, replace ’distributed’ with ’corrected’

Answer:

We shall make this correction in the final version.

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P72, L15-16: replace with ’hydrological functions constructed with the modeling framework SUPERFLEX (Fenicia et al. 2011)

Answer:

We shall make this correction in the final version.

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P72, L20-21: Add the notations S_u, S_s etc. after the mentioned reservoir.

Answer:

We shall make this correction in the final version.

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P72, L24: Are the precipitation and temperature corrected for elevation as well?

Answer:

Yes, they are. We shall make this correction in the final version.

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P75, L7: give unit for R_f

Answer:

We shall make this correction in the final version.

——————————————-

P74, L3: change into ’: : : core of the hydrological models used in this study, : : :’

Answer:

We shall make this correction in the final version.

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P74, L14: add the before soil routine

Answer:

We shall make this correction in the final version.

——————————————-

P74, L14-15: give units for R_f and D

Answer:

We shall make this correction in the final version.

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P74, L21: why is C_e not calibrated? Or are there good reasons to fix it at 0.5?

Answer:

During the model testing phase it was found that parameter C_e was not very sensitive in the range between 0.4 and 0.6 doing automatic calibration. Therefore considering large number of free parameters in the models and the successful application of this fixed

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value in previous research (Savenije, 1997) , we fixed it at 0.5 to prevent equifinality by compensation with Sumax.

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Section 4.3.2: Give the total number of parameters that has been calibrated.

Answer:

We shall make this correction in the final version.

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P79, L10: add areal before proportions

Answer:

We shall make this correction in the final version.

——————————-

P79, L23: add is before not

Answer:

We shall make this correction in the final version.

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P84, L22-23: remove other than previous models

Answer:

We shall make this correction in the final version.

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P84, L23-24: rephrase: which is, according to Westerberg et al. (2011), a more convincing than exact hydrograph simulation.

Answer:

We shall make this correction in the final version.

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P84, L28: add semicolon after characteristics.

Answer:

We shall make this correction in the final version.

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P91, L16: add an before eco-hydrlogical

Answer:

We shall make this correction in the final version.

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P91, L16-17: replace 'on the other hand' with 'Also'

Answer:

We shall make this correction in the final version.

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P93, L93: It may be better to say that this is outside the scope of this research.

Answer:

We shall make this correction in the final version.

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Table 2: please add the elevation range as well

Answer:

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We shall make this correction in the final version.

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Table 4: indicate that T_lag is used in FLEX^{L} and the other T_lag's in FLEX^{D}

Answer:

We shall make this correction in the final version.

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Figure 2: Explain what is seen in picture a-e

Answer:

We shall make this correction in the final version.

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Figure 5: Indicate better that the numbers (5m, 0.1, 3600m etc) are the criteria for different landscape classes. One may do that by adding e.g. <5m for wetland and >5m for terrace and hillslope

Answer:

We shall make this correction in the final version.

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Figure 7: Precipitation input does not equal the output. Is this change in storage caused by a real difference in the begin and end state or is it caused by a too short warming up period?

Answer:

This is a very precise observation. The precipitation input does not equal the output. This is caused by neglecting glacier dynamics. In the Upper Heihe, above a certain

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elevation the precipitation is fallen as snow all year around which is stored in glaciers. However our model does not consider glacier melt and movement, due to the limited glacier area (0.6%). Therefore the output is a little bit less than precipitation.

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Figure 9 and 10: improve the y-axes: add numbers at the $FLEX^L$ and $FLEX^D$ graphs and add labels for precipitation and temperature.

Answer:

We shall make this correction in the final version.

—————————————-

References

Fenicia, F., Savenije, H. H. G., Matgen, P., and Pfister, L.: A comparison of alternative multiobjective calibration strategies for hydrological modeling, Water Resour. Res., 43, W03434, 10.1029/2006wr005098, 2007.

Gharari, S., Hrachowitz, M., Fenicia, F., Gao, H., and Savenije, H. H. G.: Using expert knowledge to increase realism in environmental system models can dramatically reduce the need for calibration, Hydrol. Earth Syst. Sci. Discuss., 10, 14801-14855, 10.5194/hessd-10-14801-2013, 2013a.

Gharari, S., Shafiei, M., Hrachowitz, M., Fenicia, F., Gupta, H. V., and Savenije, H. H. G.: A strategy for "constraint-based" parameter specification for environmental models, Hydrol. Earth Syst. Sci. Discuss., 10, 14857-14871, 10.5194/hessd-10-14857-2013, 2013b.

Kavetski, D., and Fenicia, F.: Elements of a flexible approach for conceptual hydrological modeling: 2. Application and experimental insights, Water Resour. Res., 47, W11511, 10.1029/2011wr010748, 2011.

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Savenije, H. H. G.: Determination of evaporation from a catchment water balance at a monthly time scale, Hydrol. Earth Syst. Sci., 1, 93-100, 10.5194/hess-1-93-1997, 1997.

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Table 1. The averaged results of all the points on the Pareto front of three objective functions of the five models $FLEX^L$(lumped model), $FLEX^D$ (semi-distributed model with same parameters sets for different Thiessen polygons) $FLEX^{D1}$ (semi-distributed model with different parameters sets for different Thiessen polygons) $FLEX^{T0}$ (FLEX-Topo model without constraint) and $FLEX^T$ (FLEX-Topo model with constraint) in calibration, split-sample and nested sub-catchments validation.

	Calibration			Split-sample validation			Zhamashike validation			Qilian validation		
	I_{NS}	I_{NSF}	I_{NSL}	I_{NS}	I_{NSF}	I_{NSL}	I_{NS}	I_{NSF}	I_{NSL}	I_{NS}	I_{NSF}	I_{NSL}
$FLEX^L$	0.82	0.99	0.87	0.79	0.95	0.78	0.54	0.79	0.56	0.56	0.87	0.59
$FLEX^D$	0.81	0.99	0.84	0.74	0.94	0.76	0.56	0.83	0.6	0.53	0.84	0.58
$FLEX^{D1}$	0.82	0.99	0.85	0.80	0.96	0.83	0.58	0.84	0.63	0.38	0.67	0.44
$FLEX^{T0}$	0.82	0.99	0.84	0.80	0.97	0.84	0.60	0.89	0.70	0.68	0.90	0.71
$FLEX^T$	0.80	0.98	0.84	0.78	0.95	0.82	0.65	0.92	0.74	0.71	0.96	0.75

Appendix

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 10, 12663, 2013.

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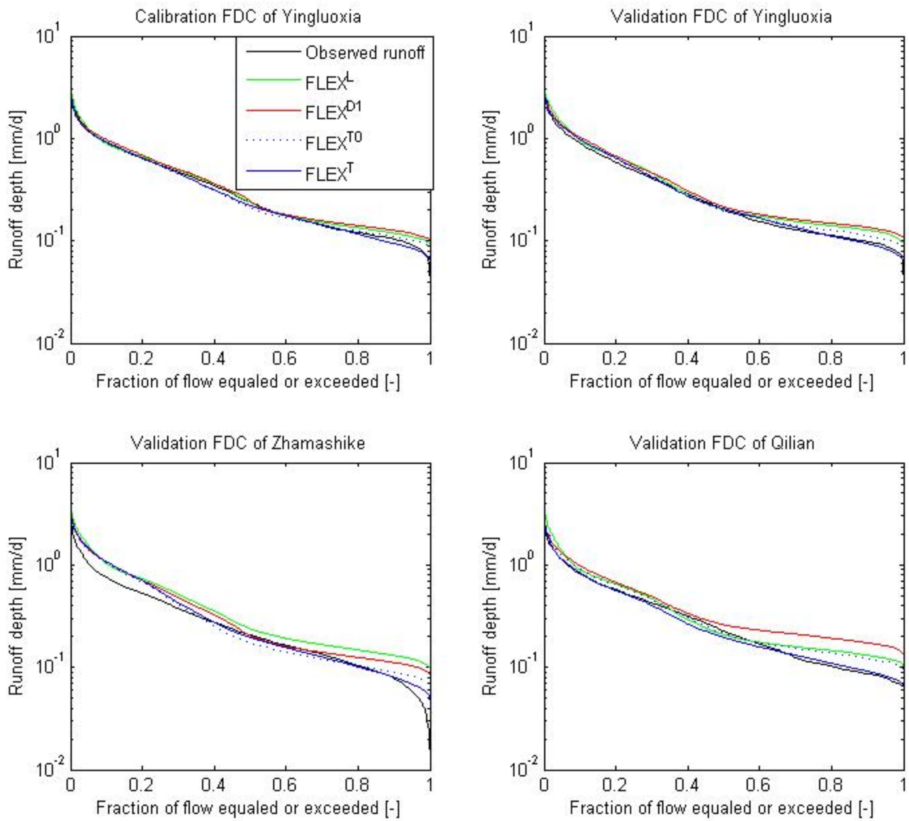

Fig. 1. Flow duration curve of four models

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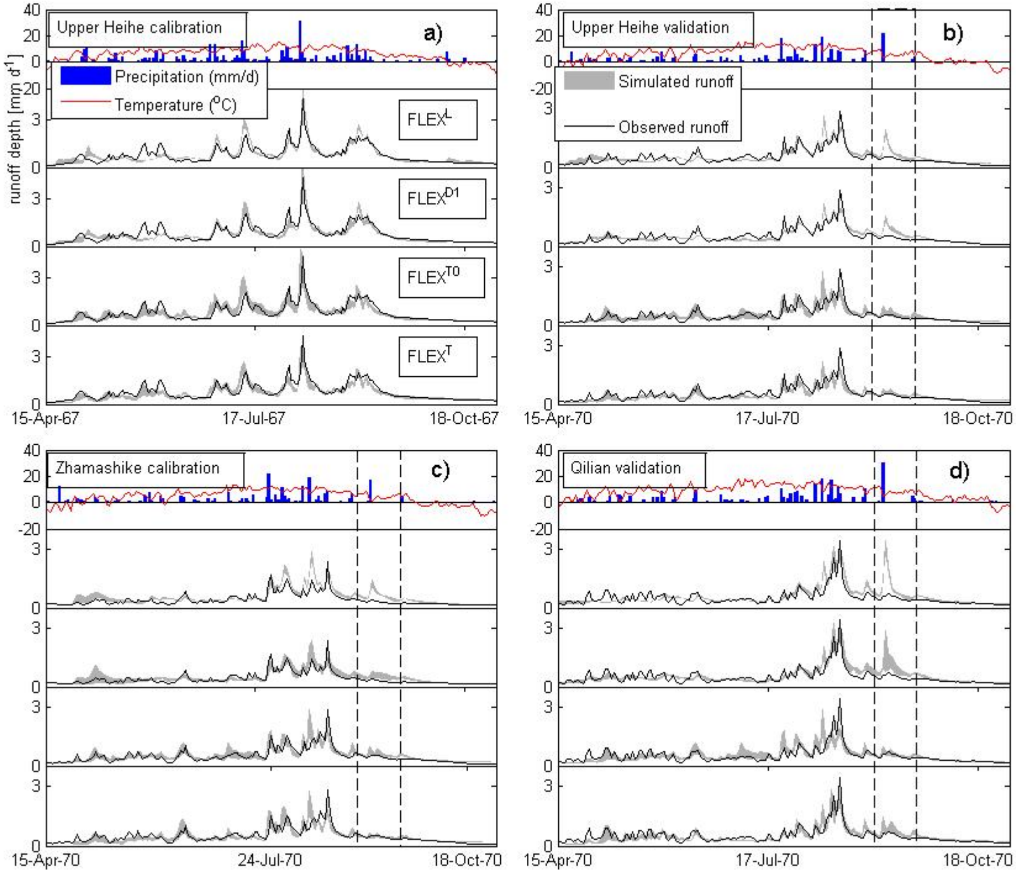

Fig. 2. Simulated hydrograph of four models

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