**Hydrology and
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Discussions**

Interactive comment on "Towards reconstruction of the flow duration curve: development of a conceptual framework with a physical basis" *by* Y. Yokoo and M. Sivapalan

Anonymous Referee #3

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Towards reconstruction of the flow duration curve: Development of a conceptual framework with a physical basis

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1) Overview

This study presents, in a hypothetical setting, an investigation of the climatic and land-

scape controls on the shape of the flow duration curve (FDC) with the use of a stochastic rainfall generator and a lumped physically-based rainfall runoff model. The sensitivity of the simulated FDC shape to a variety of combinations of climatic inputs (i.e. precipitation, potential evaporation and their within year phase) and landscape properties (i.e. soil type and depth) were investigated through changing corresponding model parameters. The results indicated that the FDC can be disaggregated into two components: surface runoff and subsurface runoff. Moreover the authors argue that the surface runoff can be approximated with the use of a non-linear filter on the precipitation duration curve, whereas subsurface runoff can be approximated with the use of a linear filter on the FDC constructed from the regime curve. A correction to the lower tail of the FDC is also suggested to capture the effects of high evapotranspiration at low flows. The authors conclude that the FDC can be reconstructed for the ungauged basins with the use of the above three-step conceptual framework.

2) General Comments:

This study is a purely theoretical study that aims to identify the dominant controls on the shape of the flow duration curve (FDC). The authors try to utilize the understanding gained from hypothetical simulation experiments to derive FDCs for ungauged basins. I think one of the main drawbacks of the study is that it is purely theoretical and based on a limited number of experiments with a lumped (quasi 2-D) rainfall runoff model. Although in the discussion section the authors mention that they will investigate the proposed framework in some 200 watersheds in the U.S., I still think that the proposed framework should be demonstrated with observed data in one or more real watershed systems in the current manuscript before it could be accepted for publication.

I think the link between the regime curve and the intermediate segment of the FDC is a unique contribution of this manuscript. For that reason, the description of the regime curve should be clarified and the link between the regime curve and the intermediate segment of the FDC should be more rigorously discussed. Some points of discussions are provided in the main comments section.

I think the manuscript will eventually make a good contribution in the subject area of prediction in ungauged basins and the topic is suitable and interesting for the HESS readership. However, the manuscript should be revised based on the comments provided in this section and sections listed below before it could be accepted for publication.

Main Comments:

1) The authors need to explain clearly that they are focusing on "runoff" rather than "streamflow" which is the main variable used for constructing FDCs. When streamflow is used to construct FDCs watershed size and routing parameters strongly influence the shape of the FDC. A discussion on the runoff vs. streamflow use in constructing FDCs should be provided. Make it clear that runoff is used in this manuscript. 2) Hydrologists would like to see a hydrograph, or in this case, runoff time series to understand the behavior of the watersheds. Please include at least one time-series graph showing rainfall, surface and subsurface runoff components before transforming into FDC. I suggest providing this for Figure 2.

3) Page 3975, Line 4-13: I think the authors need to provide a more process based explanation to this contradiction based on the model structure. Why do authors think that sand provided steeper slope compared to silt considering the processes embedded in the model? The explanations given in Ward and Robinson (1990) are more related to flashy vs. delayed response of watersheds based on the soil hydraulic conductivity values. It appears that macropores and preferential flow is blamed without evidence.

4) Page 3976, Line 11: It is not clear why shallow soils should have smaller water holding capacity? To my knowledge water holding capacity is a function of soil type and composition and is independent of soil depth (it may get slightly lower with depth due to compaction). Do you mean "limited moisture supply"? Please clarify in text.

5) Page 3978, Lines 4-18: None of these points has been mentioned during the simulation results presented in the previous sections. This paragraph seems to be out-of-

context. I suggest removing this paragraph.

6) Page 3979, Line 4: I think this is an over-statement. In soils with high hydraulic conductivity, soil depth (shallow vs. deep) will be a significant factor in surface runoff generation due to saturation excess mechanism.

7) It appears to me that the link between the regime curve and mid-segment of the FDC will hold for basins with base flow dominated response, where the flashy behavior of the flow is smoothed out. In flashy watersheds, dominated by the surface flow, this link may no longer hold. In the manuscript, sensitivity to climate factors and soil type utilized 8m deep soil which will provide more sustained flows. I wonder how the results will change if 6m deep soil was used? Moreover, there will possibly be problems in snow dominated basins.

8) Page 3979, Lines 20-29: Please provide more details on how this framework will be applied in ungauged basins. Should we estimate the parameters of these models from similar gauged basins and apply these models in ungauged basins? I think these procedures should be explained more explicitly. Moreover, they should be demonstrated with observations in one or more watersheds.

Minor Comments:

Page 3962, Line 6: "PFDC" Not clear why "F" is used in "Precipitation duration curve". I suggest changing "PFDC" with "PDC".

Page 3962, Line 14: The description of the regime curve is not clear. The term ensemble is generally associated with multiple runs of a model. Also time step is not clear. Since there are 12 points on Figure 2-5, does this mean regime curve is long-term mean flow value for each calendar month? Describe the regime curve more clearly. Because we do not see the regime curve itself but its FDC, it is really difficult to understand what it really means with the current descriptions provided in the manuscript.

Page 3963, Line 2: "temporal streamflow variability" This sentence is rather confusing

because FDC does not contain any temporal information, but contains frequency distribution of flow within a specific "time period". I suggest replacing this sentence with a more common definition of FDC provided in many references cited in the manuscript. One can also construct the FDC for any time averaging scale such as hourly, daily, weekly, monthly etc. Therefore the next sentence needs to be modified to reflect this information.

Page 3963, Line 26: Replace "studied" with "studies"

Page 3964, Line 13: As far as I remember, Yilmaz et al. (2008) utilized not only one parameter but various parameters of the SAC-SMA in their sensitivity analyses. Moreover, they also provided understanding on the shape of the flow duration curve with three segments, which is very similar to Figure 7 in the current manuscript – See Paragraph 37 and Figure 5a in Yilmaz et al. (2008) manuscript. Please improve the citation as necessary.

Page 3965, Line 13: Again "regime curve" definition is not clear. The terms "ensemble mean" and "regime curve" is not explained in the cited reference (Yokoo et al., 2008). Moreover, is regime curve constructed using "runoff" as described here, or "using streamflow" as described in page 3972, Line 15?. Runoff and streamflow should not be confused: the latter includes the flow routing by the channel network.

Page 3968, Eqn 2: Replace "resisntance" with "resistance".

Page 3968, Eqn 3: Replace "seepagefaces" with "seepage faces".

Page 3970, Line 15: "zr-zs m for ys" seems to be a typo.

Page 3971, Line 21: "three different soil types". Section 3.3. provides results for only 2 soil types. Explanation needed in Section 3.

Figure 1: Correct the mismatch between "OF" in the figure and "FO" in the caption.

Figure 1: According to Table 1, the term "Z" is the depth of soil layer. Hence "Z" in the

figure should extend to the top of the "zs" but not the datum.

Figure 2: In y-axis replace Flux(m/d)" with "Flux(mm/d)"

Figure 2:Caption: Replace "within year daily variation" with ""within year daily flow variation"

Figure 2: Please explain how exceedance probabilities were calculated for each of the FDC component (i.e. SFDC, SSFDC, PFDC and regime curve). Does figure 2 mean that in 3 year time period, around 32% of the time surface runoff was observed whereas 100% of the time subsurface runoff was observed? Please explain in text.

Page 3972, Line 9: Replace "SSFDC, thin black curve" with "SSFDC, thin red curve"

Page 3973, Line 8: Replace "gradient assumed" with "gradient"

Page 3973, Line 12: Need to explain "in-phase" and "out-of-phase" cases in this description for figures 3a and b.

Figure 3: "In" and "Op" terms in labels should be explained.

Page 3973, Line 5: "semi-arid". Other descriptions for R=1.5 states "arid". Make this description the same throughout the text.

Page 3973, Line 24: I suggest replacing "predicted" with "simulated" as there is no prediction of a future event in this experiment.

Page 3974, Line 12: "silt" or "silty loam"? Correct this confusion throughout the manuscript.

Page 3975, Line 25-26: I think an important discussion is missing here. Shallow soil provides more flashy response (steeper FDC slope) whereas deeper soil provides more "sustained" flows due to increased moisture supply. Figure 5b shows that shallow soil simply dries out easily due to limited moisture content. More discussion along these lines should be digested into the text.

Page 3976, Line 1: "Fig. 5b and d" do you mean "Fig. 5c and d"??

Page 3976, Line 16: Correct the English usage. Perhaps "reason lower tail" should be replaced with "reason for lower tail"

Page 3976, Line 25: Replace "zero" with "zero.)"

Figure 6a: y-axis: Replace "Elux" with "Flux"

Figure 6: x-axis: Replace "Exceedence" with "Exceedance".

Page 3978, Line 29: Replace "variability" with "variability (PFDC)"

Page 3979, Line 16: Replace "only captured" with "only be captured"

Page 3979, Line 15: "water holding capacity" is this the correct term here? Or do you really want to emphasize "limited moisture content of the soil" which could be due to "shallow soil" or soil hydraulic properties.

Figure 4b: y-axis: Replace "FLux" with "Flux"

Page 3980, Line 3: If you have monthly flow data then please explain what you mean by "ungauged" basin.