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Hydrology and Earth System Sciences Discussions

Interactive comment on "Runoff regime estimation at high-elevation sites: a parsimonious water balance approach" *by* E. Bartolini et al.

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First of all, we would like to thank Referee 1 for his interesting comments. In the following, we will try to answer the questions one by one. Our comments are highlighted by the use of the italic font.

1. (p 961) The authors assume 30% of liquid precipitation is discharged as storm runoff. A justification for this value seems necessary. In many models this would be a calibration parameter – why is it not calibrated for this model?

One of the model characteristics is the parsimony in terms of number of parameters. This requirement is particularly important in view of the extension of the model applica-

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tion at the regional scale. For this reason the fraction of liquid precipitation that forms the storm runoff was not considered as a parameter to calibrate. However, a range of plausible storm runoff fractions (from 0.1 to 0.4) was tested in a sensitivity analysis before the final value was chosen.

2. (eq 1) The authors assume that there is no change in soil storage. A brief mention on this assumption is needed when it is introduced.

We agree. We will add a sentence to the manuscript explaining that in Eq. (1) the storm runoff is intended as the contribution to runoff formation of the soil water storage, which is assumed not to change significantly during the year.

3. (p 962) How are the effects of sub-daily temperature fluctuations parameterized?

Sub-daily temperature fluctuations are not parameterized in the model even if we are aware of their effects on snowmelt and snow refreezing. This simplifying assumption stems from the model parsimonious structure, so that the only temperature parameterization provided by the model is relative to the within-month temperature variability.

4. (p 963) The parameter sigma, which quantifies within-month variability of daily temperature, is calibrated. Why it is calibrated? Are there no records of daily temperature data with which to estimate it? How far do the calibrated values vary from the measured values?

The assumption on sub-monthly temperature variability has been undertaken with the aim of simulating the water balance also for catchments where only monthly (and not daily) measurements are available. Mean monthly temperature data are obtained by *a multi-regressive model that spatially interpolates station data depending on elevation, latitude, distance from the sea, orientation and topographic concavity. The same approach could not be applied to the daily temperature observations because daily measurements are sparser in space and their variability depends also on small scale physical phenomena. Given these premises, it is clear that σ is intended as a parameter to describe the sub-monthly variability of temperature in the absence of data. In fact, records of daily temperature are available only at some locations in the study domain. In Table 1 the characteristics of some representative stations in the study domain are reported. For the same stations, the mean monthly standard deviations of the daily temperatures are reported in Table 2, along with the annual averages. The global average value, equal to 3.11 °C, seems to confirm the value assumed for the parameter σ in the paper.*

Table 1. Characteristics of the stations

St. ID	Station Name	Basin	Elevation [m asl]
1	Aosta	Dora Baltea	583
2	Courmayeur	Dora Baltea	1220
3	Lago Gabiet	Dora Baltea	2340
4	Bardonecchia	Dora Riparia	1275
5	Ceresole Reale	Orco	1579
6	Fenestrelle	Chisone	1200
7	Crissolo	Po	1410
8	Val Noci Diga	Scrivia	544
9	Usseglio	Stura di Lanzo	1310
10	Ormea	Tanaro	730
11	Lago D'Avino	Toce	2220

5. (p 968) Why is the bias distributed equally among months? Why not in proportion to Pj?

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Table 2. Monthly standard deviation of daily temperature, σ, expressed in °C

St. ID	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1	4.29	2.80	1.72	2.39	2.20	2.55	2.15	1.86	2.09	2.78	2.39	3.93	2.60
2	3.70	3.62	3.48	-	-	-	-	-	-	-	-	3.84	3.66
3	4.50	4.13	3.64	3.53	2.79	2.99	2.93	2.71	3.04	4.09	-	-	3.44
4	-	3.97	3.81	3.32	2.91	-	2.75	2.54	2.85	3.54	-	-	3.21
5	3.92	3.91	3.55	3.07	3.32	-	2.78	2.54	2.99	3.25	3.51	3.69	3.32
6	4.83	3.95	2.56	2.91	2.56	3.22	2.83	2.34	2.81	3.38	3.16	4.50	3.25
7	1.53	2.01	2.09	2.08	3.61	2.36	2.66	2.69	1.48	3.33	1.19	1.96	2.25
8	3.05	2.74	-	2.62	2.90	2.56	2.38	2.35	2.36	3.10	3.04	2.77	2.72
9	4.13	3.97	3.60	3.35	3.45	3.30	-	2.82	3.39	3.67	3.71	4.06	3.59
10	2.66	3.09	3.19	-	-	-	2.06	2.14	2.58	2.68	2.91	2.55	2.65
11	-	-	-	-	-	-	3.31	3.12	3.56	3.65	4.06	-	3.54

The model bias was not distributed proportionally to P_j because of the problem of precipitation undercatch in winter months (i.e., in the presence of solid precipitation). In fact, if the precipitation correction was distributed proportionally to the measured precipitation, less precipitation would result in winter months (where the measured precipitation is possibly "undercatched"). Nevertheless, we are aware that the uniform redistribution can be a bit simplistic and we are now investigating other mechanisms of precipitation correction redistribution that could account for seasonality.

6. (p 972) The suggestion that the discrepancy between regional and reference values of melt rate is because of use of a monthly model seems unusual. I had the impression that the model produces monthly melt by integrating over many values of daily melt, in which case the model does not operate directly at the monthly scale.

The model operates at the monthly scale while the sub-monthly temporal scale is just

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parameterized. In fact, the model does not assume a daily temperature to simulate the snowmelt, while it uses a reference positive monthly temperature (T^{+2}) that is applied for the fraction of month characterized by positive temperature. We believe that the discrepancy between regional and reference value of the melt rate may rather be due to the impossibility to take into account the temperature condition just before snowmelt (i.e., antecedent temperature index, cold content of the snowpack) when working at the monthly time scale. This implies that snowmelt is triggered whenever the melt conditions are met, without taking into account the effective snowpack conditions.

7. (Fig 6a 6b) It seems curious that the QI values for the regional model are better than those for the individual calibrated case, for these two basins.

The QI of the regional model application cannot be directly compared with the QI of the local model application. In fact, to calculate the QI, it is necessary to assign a score to the model bias and the MAE, among other indicators. In details, the procedure to score the MAE requires the following steps: i) the MAE of all the 39 basins are considered; ii) the interval comprised between the minimum and maximum MAE is divided into 5 equiprobable classes, whose limits are its 0.2, 0.4, 0.6 and 0.8 quantiles; iii) a score varying from 1 to 0 (i.e., 1, 0.75, 0.50, 0.25 and 0) is assigned to each class. The range of the MAE changes depending on the model application. In particular, is lower for the local model application and larger for the regional model application. As a consequence, the same value of MAE can fall in different quantiles and so be differently scored depending on the model application. For this reason in the paper we pointed out that the QI can be used "to judge the quality of the reconstructed runoff regime by comparison with the other QI indices obtained using the same model structure" but "it cannot be used to compare results of two different modeling frameworks" (from line 25, page 978). In this respect, we recognize that the caption of Fig. 7 can be misleading because of the word "comparison". To clarify this point, the caption will be changed to "Summary of the Quality Indices QI obtained with the model application *at the catchment scale (light gray) and at the regional scale (dark gray). The basin numbers refer to the table in the Supplement".*

8. (Fig 8a) Since TEST1 is a special case of WB, with s=0, how can TEST1 slightly outperform WB for a few catchment?

Figure 8a shows the comparison between the MAE of model TEST1 (with σ=0° C) and model WB (with σ=3° C). Locally it may happen that the MAE computed after the application of the model TEST1 is lower than the MAE computed after the application of the model WR. It means that, in this specific case, the assumption on the sub-monthly temperature variability is not strictly necessary. Since this happens only in 3 basins out of 39 (and the changes in MAE are rather low), we concluded that the assumption is to be retained.

9. One of the benefits of using a process-based conceptual model is that it allows checking the internal states (here snowpack storage). It would be interesting to show an additional graph which showed monthly flow, monthly snowmelt, and monthly snow storage for the 4 catchment. This would illustrate the models predictions of differences between catchments in runoff generation mechanisms, and produce a testable hypothesis on snowpack storage.

This is a very interesting suggestion, since we were debating on the possibility of inserting the figure that Referee 1 is mentioning. In order to better demonstrate the way snow processes are simulated by the model, the average monthly runoff, snowmelt and snow storage for the 4 basins used in the results presentation are reported in Fig. 1. The effects of elevation on runoff formation in terms of snow contribution are shown in Fig. 2a and 2b.

10. (p 966) line 12 should "rainfall" be "infiltration"?

From a physical point of view the referee is right and "rainfall" should be changed into "infiltration". However, from an operational perspective, the water that sustains evapotranspiration in the model is the rainfall since no soil water storage is modeled.

11. (p 966) eq 12b should Pj* be 0.7Pj*?

Yes, it should be. We will correct it in the final version of the paper. Thanks a lot for pointing out this mistake.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 8, 957, 2011.

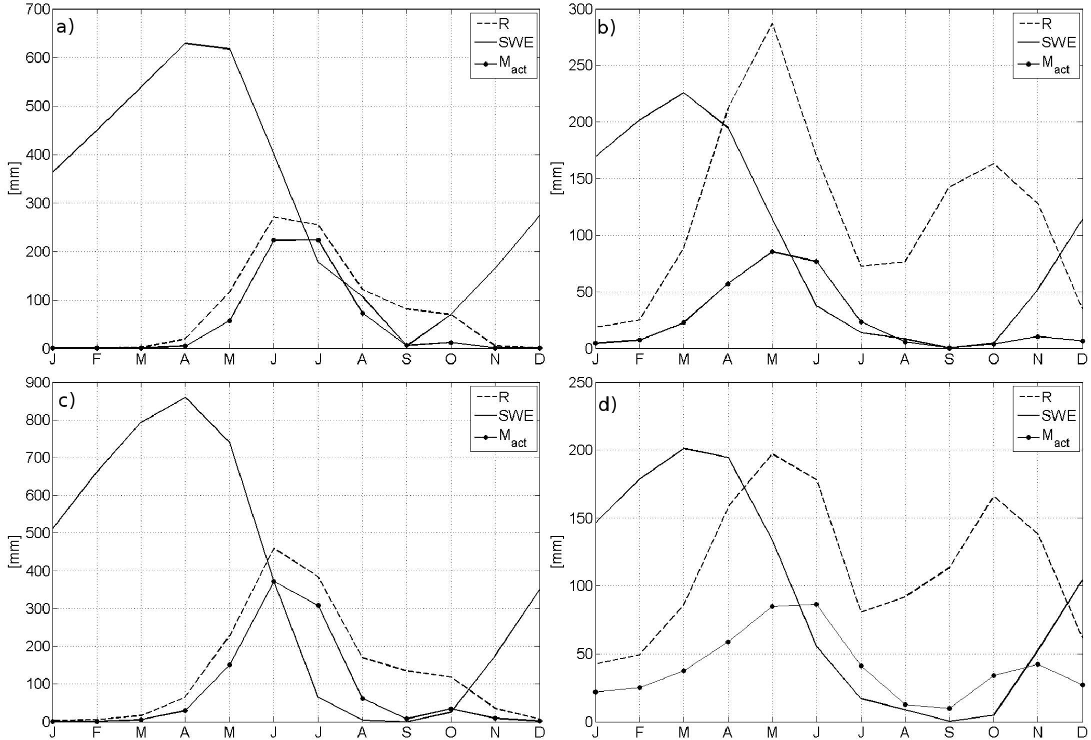

Fig. 1. Average regimes of runoff, R, snow water equivalent in the snow storage, SWE, and actual snowmelt, M_act. a) Savara at Eau Rousse; b) Sesia at Ponte Aranco; c) Rutor at Promise; d) Toce at Candoglia

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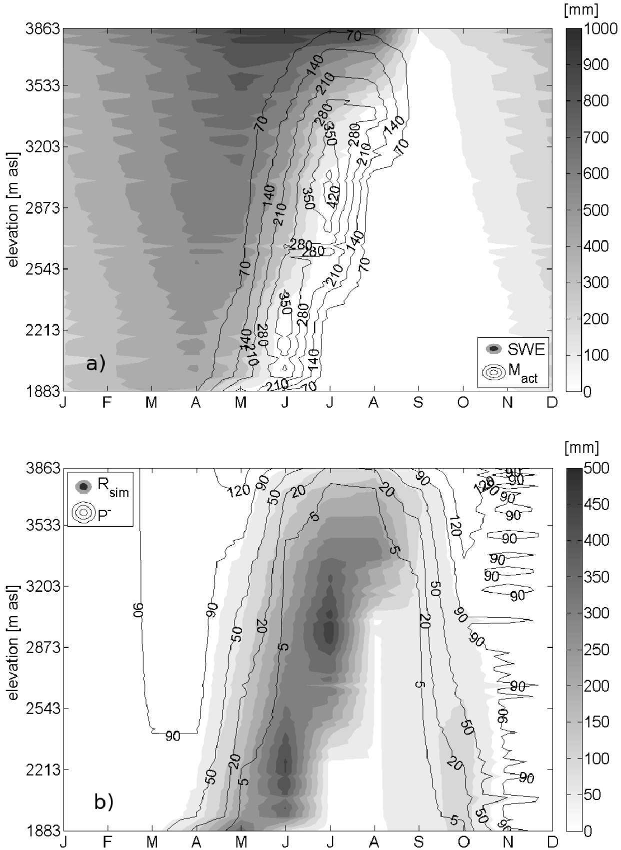

Fig. 2. Effects of elevation distribution on runoff production – River Savara at Eau Rousse. a) SWE present in the snow storage and snowmelt, M_act; b) Snowfall, P-, and runoff, R

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