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Discussions

Interactive comment on "Effective rainfall: a significant parameter to improve understanding of deep-seated rainfall triggering landslide – a simple computation temperature based method applied to Séchilienne unstable slope (French Alps)" *by* A. Vallet et al.

A. Vallet et al.

aurelien.vallet@univ-fcomte.fr

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First of all we would like to thank the referee #1 for his very detailed discussion of the manuscript. A point-by-point response to the comments is as follows:

"The title shows the dilemma already: The effective rainfall is the main topic of the paper and landslide aspects are only of minor interest. The improvement of the under-

standing, how deep seated landslides work, and what effective rainfall and landslides have to do with each other is nearly not regarded. The question is more, if the paper is a valuable contribution to the understanding of effective rainfall processes and process quantification." –> We understand that the proposed title is a bit too ambitious and brings confusion relatively to the manuscript purposes: i.e. to develop a method to estimate effective rainfall with a parsimonious dataset and to show that effective rainfall is a significant parameter for deep-seated landslide studies. In addition, the method is not only temperature based as DEM, aerial photography and auger holes are required. As consequences we proposed to simplify manuscript title as followed: "Effective rainfall: a significant parameter for deep-seated landslide studies – A parsimonious computation method applied to Séchilienne unstable slope (French Alps)"

"In this terms the paper proposes some kind of effective parameter calculation on a local scale which cannot easily be transferred to other sites and additionally it may not be helpful for the investigated site, too."

–> The purpose of this paper is to develop a method which can be transferred to other sites, obviously parameters computed are representative of the local conditions (they can be used at a regional scale with precaution) but must be recomputed for other sites using the proposed method. "There are already numerous proposed methods, only the lack of data makes it difficult to use these methods at the investigated site."

–> In addition of the lack of data issue, all the proposed methods, except the Penman-Monteith needs to be calibrated for local/regional conditions against the Penman-Monteith equation.

"This seems to be clever, but the question is, if it is reasonable and helps scientifically and not only technically."

–> Substitution methods used for this study have been demonstrated scientifically and are used in numerous studies (Almorox, 2011; Bristow and Campbell, 1984; Samani, 2000). Especially, Almorox (2011) says: " Temperature based models provided less accurate results, of which the best one is the Bristow and Campbell model (coefficient of determination = 0.892). The Hargreaves and Samani model is simple and are recommended to estimate the daily global radiation when only temperature data are available and when the coefficients cannot be determined."

"The concepts even for the temperature calculation (which is not measured on site!) remain on a low statistical level and they are not connected to the local conditions (a height-dependency curve of the temperature with the weather stations around the site would be very helpful)."

–> Since the manuscript has been submitted, we are using a new weather station (named Mure, 15 kilometers away from Séchilienne), which we didn't manage to have accessed before, in order to replace the station of Mont Falcon used for the temperature estimation on site. This station has the advantage of (i) having a longer interval (1992 to now instead of 2004 to now for Mont falcon), and (ii) having a local environment similar to Séchilienne watershed whereas Mont Falcon was located at the bottom of the valley on the opposite slope of Séchilienne landslide (having daily temperature amplitude significantly higher). Temperature estimation with Mure station has improved significantly the temperature site estimation. On the same period, the coefficient of determination (R2) of the correlation between Mure-Luitel relationship (0.894 and 0.915 for min. and max. temperatures respectively) were far higher than the ones from Mont Falcon-Luitel temperature relationship (0.839 and 0.849, min. and max. respectively). As an example R2 of the correlation between effective-rainfall with AWS of 25 mm and displacement was improved to 0.678 (n = 212; α = 0.0338; β = 1) instead of 0.633 (n = 212; α = 0.0335; β = 1) with Mont Falcon on the same period. New results have been computed by taking also into account a new crop coefficient (Kc) value updated after referee 3 comments. In addition, Mure station allows us to compute effective rainfall on a longer interval (increase statistical level of effective-rainfall detrended displacement correlation from 1994 to 2012 instead of 2004 to 2012 with Mont falcon). The new correlation period has significantly changed the method, day extension and lag involved

for best computation of each scenario of sensitivity analysis. Indeed, a new best correlation is performed with an AWS of 95 mm (n = 119; α = 0.1585; β = 1: details in revised manuscript) which is more relevant with field observation. New best R2 is 0.6 for effective rainfall whereas R2 is only 0.3 for gross rainfall. We are now using these new results for our research (modelling, rainfall threshold…) and we proposed to use this station in the revised manuscript and to quantify the relationship between water input and displacement output on a longer interval (1994-2012). Concerning the low statistical level, we have implemented permutation test method which shows that R2 are significant. In addition R2 obtained with Mure station for temperature estimation is significantly higher, which increases the statistical power of the relationship. Finally, the correlation of temperature time series between two local stations takes implicitly the local conditions into account and at a daily rate. In addition, the height-dependency curve is dependent of the sample rate (annual, monthly, ten-day period) and of the temperature parameters (minimum, maximum, mean, amplitude). By using a direct daily correlation, we maximise the accuracy of daily temperature estimation; this correlation constitutes a height dependency curve between two local stations at a daily resolution.

"This additionally focuses the question of the influence of the unsaturated zone: Normally the averaging of (effective) rainfall/recharge impact increases with depth to groundwater. At a site with depth to groundwater of several 10 m to several 100 m as described in the paper, the recharge should be averaged to a weekly or even monthly constant rate. Of course the described high conductivity of fissures and fractures leads to an overcompensation of the averaging effect, but this is not directly connected to evapotranspiration, as is also shown in the only minor effect on correlation coefficients (0.8 with effective rainfall instead of 0.66 with rainfall only)." "The distribution of vegetation, the exposure to solar radiation (on a hillside!), the different depths to groundwater are not described clearly…"

–> We agree with the fact that the deeper the aquifer, the more averaging its recharge, but the unstable slope is not a homogeneous media: several flowpaths are slow, and would validate a monthly averaging, whilst others are very rapid, on a daily time step (demonstrated by tracer tests), and require a daily calculation

–> Distribution of vegetation has been taken into account to estimate the runoff, AWS and, after comments of referee 3, also to estimate the crop coefficient Kc. Obviously, exposure to solar radiation, unsatured zone and several other parameters can be taken into account to improve the estimation of effective rainfall, but at the price of more complexity. However, our purpose is to develop a relatively simple and parsimonious computation method which gives a sufficient accuracy for effective rainfall estimation. On another hand, comments point out that our method is maybe too complicated ("it is possible, that simpler calculations may lead to similar results"). Decisions have to be made to build a model in order to balance computation accuracy versus complexity according to the purpose of the model. This is why, we choose to keep only the main factors which influenced effective rainfall estimation (AWS, runoff and evapotranspiration) in the purpose to work with the appropriate input signal useful for landslide studies.

". . .the evident question remains, if a daily calculation of the actual evapotranspiration and effective rainfall is necessary or if a monthly (or weekly) calculation based on the simple and only temperature dependent method of Thornthwaite (1948) is not sufficient, perhaps with a daily calculation of daily rainfall minus average monthly/weekly evapotranspiration?"

–> We have tested the monthly proposed method with the following results: Figure 1 and 2 show that proposed method ET0 differs a lot from the one computed with manuscript method.

–> Rainfall minus average monthly/weekly evapotranspiration, even with daily evapotranspiration has no physical meaning, sol interface is completely disregarded and this will lead to bias and skew effective rainfall estimation. As an example, Figure 3 shows the comparison of effective rainfall computed with our method and the effective rainfall

estimated with the proposed method using both the same actual evapotranspiration (the one computed by our method). Figure 3 shows that proposed method differs a lot from the one computed with manuscript method.

"The statement of better performance of PMred ET0 compared to the other tested methods should be stated by numbers in the text, too, not only in Table 3." "Even an explanation of the result (3% instead of 14% as explained before) is missing." "Fig. 5 should be colorized, especially the graph with effective rainfall and rainfall."

–>Revised manuscript has integrated these remarks.

"It also remains open, if a correlation of the data of one of the weather stations with full dataset (and therefore without any technical substitution, just based on the equations of FAO etc.) would give the same (or better?) result as all the local adaptation."

–> These are very relevant remarks, which we have considered before performing this study. The answer will depend upon the study context. First able, this will be possible only if such stations (measuring all the required parameters) is located in a similar environment/context (elevation/wind/exposure to sunshine/surrounding topography/vegetation (valley/forest/lake which will buffer or amplify the estimated ETP)) of the target watershed. In our cases, Saint-Michel-Maur (698 masl) and Grenoble Saint-Geoirs (384 masl) weather stations do not fulfil this previous statement (Séchilienne watershed about 1100 masl). Saint-Nicolas weather station can be used with high precautions (valley orientation and vegetation cover different of Séchilienne site). Secondly, such stations should have a recording period interval which matches with the study purpose, here displacement dataset period (1992 to now), which was limited from 2004 in discussion paper due to Mont Falcon data extension. So Grenoble-Saint-Geoirs (July 2009 to now) is disregarded. Finally, by using another station to compute ET0, there is no possibility to know how the estimation is biased by using another site (no comparison element). ET0 computed with FAO Penman-Monteith equation was performed at Saint-Nicolas weather station and compared to the ET0 obtained with our method (Figure 1). Figure 1 shows that proposed method ET0 differs a lot from the one computed with manuscript method.

“Table 4 is unclear to me: What do the numbers in brackets say? Does the geology at the surface change with the percentage of PIS?”

–> The numbers in brackets refer to preferential infiltration structures (PIS) rise up to 85% of the watershed in order to take into account heterogeneous spatial distribution of infiltration (as indicated in the figure caption). A variation of PIS does not yield to a physically spatial change of the subareas. Indeed, their relative proportions do not change when PIS varies. Increase of PIS proportion corresponds to an increase of the PIS contribution to the part of the infiltrated water which flow to the Séchilienne unstable slope. To resume, for the homogeneous infiltration assumption, subareas are defined by spatial area proportion whereas for heterogeneous infiltration assumption the subareas are defined by their contribution proportion or weigth. This point will be explained in the revised manuscript.

“It would be good to have in fig 9 the detrended displacement in each of the other three scenarios as a colored curve and either R2 or the correlation coefficient given for each scenario.”

–> The detrended displacement is the same for all the scenarios as we only modified the input signal by varying the PIS proportion. Technical corrections have been added to the revised manuscript.

“My overall impression of this paper is that there are difficulties to structure the text thoroughly (some explanations are double, the reference to figures and tables can be improved),. . .”

–> Manuscript will be revised to improve structure flow.

“. . .the calculations are not transparent enough (effective rainfall yes, but the other influencing factors not). . .”

–> Influencing factors will be more described and discussed in the revised manuscript

“. . .and the statistics are only rudimentary done.”

–> RMSE has been also computed to quantify goodness of fit for relationship between water input and detrended displacement

–> Permutation test method has been implemented to evaluate the R2 significance of each correlation.

–> Bootstrap method has been implemented to evaluate the significance of using effective rainfall instead gross rainfall (significance of difference between gross rainfall R2 and effective rainfall R2).

Figure 1: Comparison of ET0 estimated with paper method (ET0 Séch) (A), with proposed monthly Thornwaitt method applied at a daily rate (ET0 Thorn) (B) and with FAO Penman-Monteith equation at Saint-Nicolas weather station (ET0 FAO) (C). (D) plots the difference between ET0 Séch and ET0 Thorn whereas (E) plots the difference between ET0 Séch and ET0 FAO. (F) plots the percent error of ET0 Thorn relatively to ET0 Séch whereas (G) plots the percent error of ET0 FAO relatively to ET0 Séch.

Figure 2: Summary table of Relative Error (RE) and statistic of percent error for proposed monthly Thornwaitt method applied at a daily rate (ET0 Thorn) and of FAO Penman-Monteith equation at Saint-Nicolas weather station (ET0 FAO) relatively to ET0 estimated with paper method (ET0 Séch)

Figure 3: Comparison of Effective Rainfall (ER) estimated with paper method (ER Séch), with proposed method applied (ER proposed) at a daily rate (A and B) and annual rate (C). (D) plots the difference (daily rate) between ER Séch and ER proposed whereas (E) plots the percent error of ER proposed relatively to ER Séch (annual rate).

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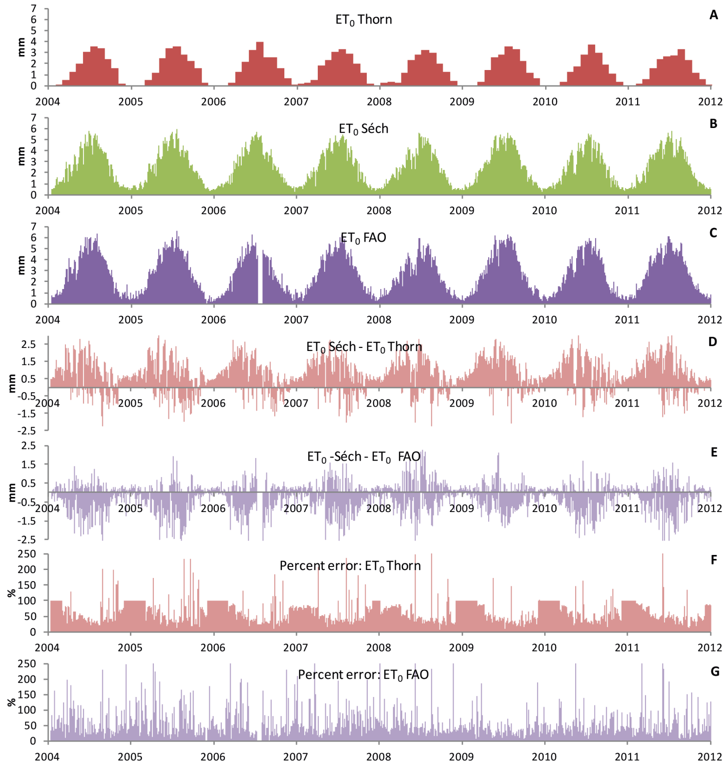

Fig. 1.

		ET0 FAO	ET0 Thorn
Relative Error		0.23	0.38
Percent error (%)	Min	0.00	0.01
	Quartile 2	9.49	22.94
	Median	20.10	42.69
	Quartile 3	38.42	79.10
	Max	425.55	300.99

Fig. 2.

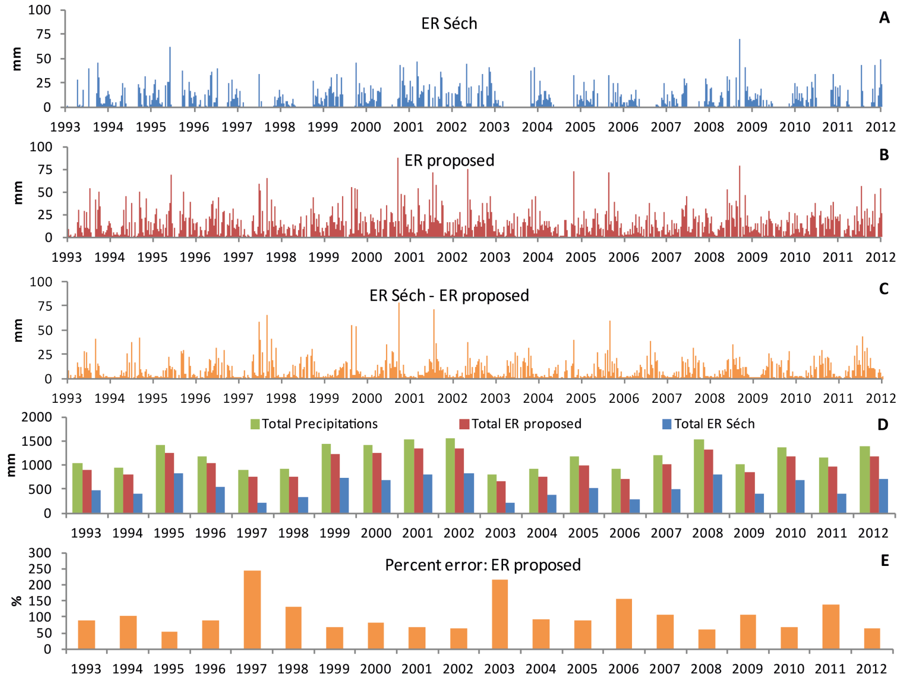
ER Séch
A
ER proposed
B
ER Séch - ER proposed
C
Total Precipitations
Total ER proposed
Total ER Séch
D
Percent error: ER proposed
E
mm
%

Fig. 3.