

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.

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Thank you for considering our manuscript and for your useful review comments. A point-by-point response to the comments is as follows:

General comments:

For the Séchilienne landslide, involving deep failure, soil antecedent moisture does not

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have great influence on destabilisation, contrary to groundwater process. The aim of this paper was to underline that a groundwater approach/reasoning is required for this kind of site. However, we completely agree with Dr. Brocca concerning the possible advantage of using effective rainfall (which implicitly take into account soil moisture in a single parameter) rather than total rainfall for shallow landslides. We will point out this transversal application in final revised paper.

Displacement data used for this study are monitored and managed by CETE of Lyon (<http://www.cete-lyon.developpement-durable.gouv.fr>), a French public administration service, with which we have signed an agreement to access data, thanks to a common research program named SLAMS, funded by the Agence Nationale de la Recherche. We are only data user, and to access the data, scientists have to contact directly the CETE. However, an observatory, named OMIV, has been implemented on four French landslides (two shallows and two deep seated ones, including Séchilienne) with open access to a wide range of data (seismic, spring flow, hydrochemistry, displacement, weather data...). For now, data extension is lesser than the one presented in this paper as OMIV was set up recently, but data are currently acquired and this on a long term perspective. We recommend you to visit the OMIV website (<http://omiv.osug.fr>).

Specific comments:

1 The aim of this paper is not to develop a prediction method for landslide displacement, but to show that effective rainfall is a significant parameter to use rather than raw rainfall in landslide study as we indicate as the end of the introduction: “The purpose of this study was to develop a simple method to take into consideration effective rainfall in landslide scientific studies with limited meteorological data on a daily time interval. (...) To demonstrate the contribution of effective rainfall in the understanding of rainfall landslide relationships a simple correlation approach between effective rainfall and displacement signals was performed.”

Indeed, relationships between input water and deep seated landslide destabilisation

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are complex (Berti et al., 2012). For this study, we used a simple linear correlation, only to show that effective rainfall is more valuable than raw rainfall, but we never intended to predict displacement. For us, a linear correlation is not enough robust and is too simplistic to characterize the precipitation-displacement relationship. On our side, we are currently working on a multi-reservoir model which uses effective rainfall, computed with the method proposed by this paper, as an input to predict Séchilienne displacement. This model achieves great performance, by far better than the one presented in this paper. We will clarify the aim of the study in the introduction and add a reminder in the chapter 2.8. Anyway, most of bibliographic references provided by Dr. Brocca are relevant for our study as they show that:

(Belle et al., 2013; Zhang et al., 2006) are using raw rainfall as model input, taking into account effective rainfall could have improved their study results

(Van Asch et al., 1999) highlight that evapotranspiration is a key factor to take into account for deep landslide study.

(Brocca et al., 2012; Ponziani et al., 2012) show that antecedent moisture is a relevant parameter to take into account for shallow landslide study and show the potential transversal application of effective rainfall which explicitly take into account this parameter for shallow landslide study. In addition, linear correlation is used to characterize the link between input (soil antecedent moisture/rainfall) and output (extensometer) (Brocca et al., 2012).

(Prokešová et al., 2013) use evapotranspiration as a threshold to exceed by precipitation to produce infiltration with no soil antecedent moisture taking into account. In addition, evapotranspiration equation is not calibrated. The use of a proper soil water balance with an estimation of AWS and an evapotranspiration equation calibrated could have improved significantly the result of this study.

2 Chapter 3.5 named “Effective rainfall computation” presents the final calibrated equation to use for Séchilienne (Penman-Monteith reduced set evapotranspiration equation,

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combined with Bristow and Campbell solar radiation equation) followed by a second calibrated equation option, with lower performance but effortless to implement. We understand that chapter 3.5 can be unclear for the reader and we will revise it to underline the final equation to use. In addition, we will mention equations used to establish figure 7 and 9 and we have noticed that also day extensions of cumulative period used are also missing and we will mention them as well.

Figure 5 has been modified in order to integrate parameters used which make the figure more understandable.

AWS and runoff estimation, developed for this study, involves a wide range of input data (DEM, Aerial pictures, Geology map and auger holes) and combination between them to estimate average value of AWS and runoff at catchment scale. Method used can be qualified as a composite GIS approach, i.e., catchment spatial heterogeneity was taken into account in order to have a spatial average estimation of AWS and runoff coefficient at catchment scale. Preferential infiltration structures (PIS) have been added, to take into account infiltration spatial heterogeneity on catchment as a single parameter. We agree with Dr. Lucca that a summary scheme figure can clarify the method and chapter, so figure 3 of discussion paper was modified to integrate the composite GIS method (Figure 1). In addition this chapter will be modified to clarify the method for the reader.

3 In our method, runoff is qualified as “important” as it plays the role of cut off of extreme precipitation events. However, runoff volume loss is low, compared to the evaporation volume loss (figure 5 of discussion paper). Detrended displacement time series related to hydrosystem groundwater saturation show seasonal variations (high in winter/spring and low in summer/autumn) however annual distribution of precipitation is scattered and do not show seasonal variations (Figure 2 and Figure 3), contrary to atmosphere temperature, meaning that evapotranspiration is the main process which affects groundwater recharge. Shifting and signal difference between seasonal variation of detrended displacement and temperature is due to system inertia.

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“Indeed, evapotranspiration is the major factor influencing the effective rainfall signal. Runoff also plays an important role in landslide development, especially in mountainous places or heavy rainfall locations. “(page 8947, lines 2 to 4)

For this reason, we should have qualified runoff as “a significant process even though minor compared to evapotranspiration, but important to take into account in order to improve effective rainfall estimation accuracy” rather than only “important”. By modifying figure 2 and by being more explicit in paragraph 2.6 we believe to have given more balanced and value to the watershed properties estimation (AWS and runoff coefficient) and reduced the emphasis on evapotranspiration calibration.

We have been through rainfall-runoff models proposed by bibliography. Proposed models (GR4J, SIMHYD, IHACRES, SMAR, HBV. . .) have been designed for hydrology purpose, i.e. to characterize catchment outlet and are not adapted for effective rainfall estimation. In addition, rainfall- runoff models required parameters calibration/estimation against water catchment outlet. For our study context, we have no information about landslide watershed outlet flow as most of the watershed discharge supply an alluvial aquifer, at the landslide base, yielding to impossibility of runoff-model calibration. We noticed that combination of MISDc rainfall-model and ASCAT method is a reliable method to compute rainfall runoff (Brocca et al., 2010a, 2010b). Soil water balance (SWB) from MISDc model (Brocca et al., 2008) is interesting. Although it requires parameters to be calibrated and has been designed for soil moisture estimation, some of the parameters can be measured, thanks to auger holes investigation and extended soil interpretation (saturated hydraulic conductivity, soil thickness, pore size distribution index) which can reduce the number of parameters to calibrate. ASCAT resolution (25km) seems to be too coarse to be adapted for a single landslide study. Soil Conservation Service-Curve Number runoff method, details in National Engineering Handbook (2004), was envisaged for this study, but this method is designed for storm rainfall event rather than daily continuous estimation (time variable is excluding). However (Brocca et al., 2010a), has adapted the method to a continuous approach by experimentally

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characterising (Brocca et al., 2009) the relationship between amount of water in the investigated soil layer estimated with SWB (AWS threshold for our study) to the antecedent wetness conditions used for SCS Curve Number method (MISDc model). However MISDc model was developed to simulate discharge only during flood events (not throughout the year) (Brocca et al., 2010b). The above described methods can improve, in some points, the effective rainfall estimation performed in our study, but at cost of more complexity and extended investigations and, most importantly, these methods require being adapted to our purpose: continuous daily estimation of effective rainfall. However as introduced in the manuscript:

“The purpose of this study was to develop a simple method to take into consideration effective rainfall in landslide scientific studies with limited meteorological data on a daily time interval. This method was designed for the hydrology non-specialist. Indeed, landslide studies involve a wide range of disciplines (seismic, structural geology, modeling, geotechnics, geophysics, and geomechanics. . .) where scientists do not necessarily have all the tools to compute effective rainfall. (page 8948 lines 22 to 27)

Because the purpose of this paper is to develop a simple method for non-specialists, and because runoff process is low compared to evapotranspiration, it has been chosen to focus study on evapotranspiration and take into account runoff with a cost effective method (time/data/complexity). The above described methods will be mentioned in our manuscript as a perspective for researchers who require more accurate estimation of runoff.

Runoff estimation method applied for this paper is similar to the well-known and commonly used “runoff rational method”. This method was chosen for its simplicity in our purpose to develop an user friendly computation method, and also because the method does not require additional data. We believe that the runoff method followed for our study is relevant for the following reasons: - method takes into account antecedent soil moisture as runoff is applied only if AWS is fulfilled (runoff estimation integrated in the soil water balance process), - , slope and vegetation cover have been taken into

account to estimate the runoff coefficient, - , runoff abacus used for this study (Sautier, 1984), has been used for another peer-reviewed study (Doerfliger et al., 1999) and a book (Musy and Higy, 2011) and finally the Sautier's abacus has been developed for Switzerland, which has similar environmental conditions as French Alps.

However, as hydrogeologists we are not specialist of runoff estimation and if Dr Brocca still disagrees with the proposed method, we are happy to have some trails to perform robust runoff estimation at the conditions that (1) proposed method does not require additional data which would limit studied period extension and also that (2) the proposed method is easy to use and to implement. Otherwise clarification made here will be added to the manuscript.

If you have the feeling that we didn't answer properly/clearly to the points you have had concerned, please let us know.

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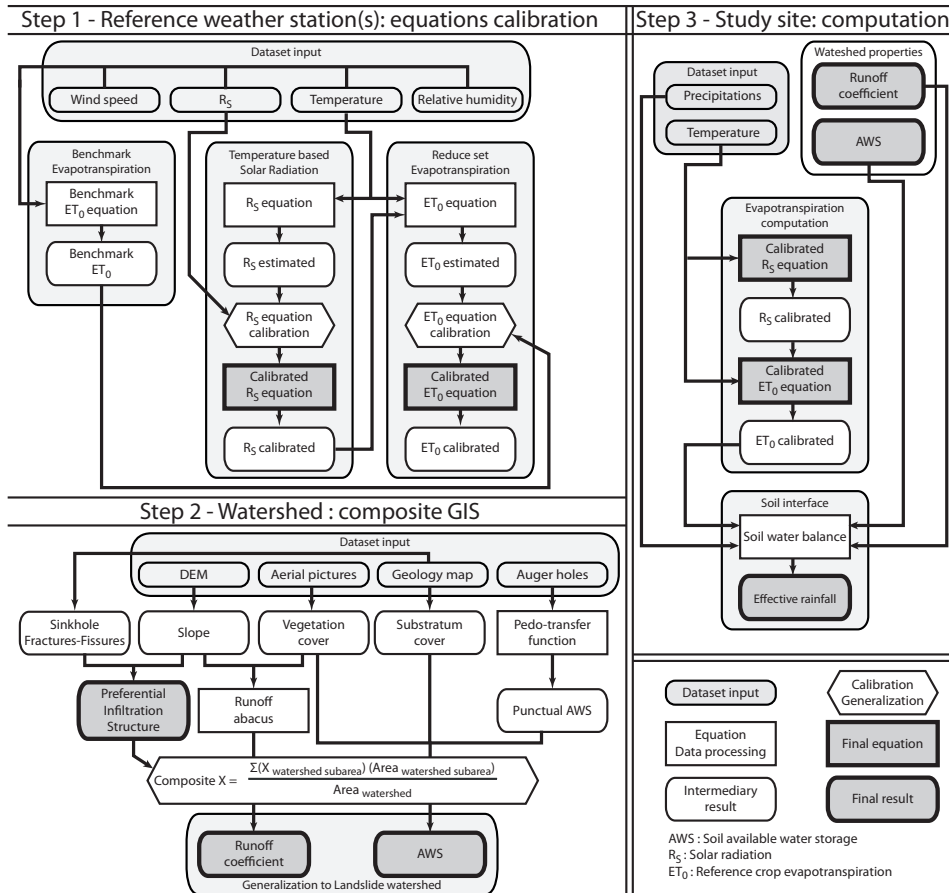


Fig. 1.

Statistics established from year 2005 to 2012												
month	1	2	3	4	5	6	7	8	9	10	11	12
average cumulated precipitations (mm)	82	64	91	102	134	104	85	121	118	84	108	126
average mean temperature (T°C)	2	3	8	13	17	19	20	19	15	13	9	4
average cumulated detrended displacement (Unitless)	35	31	36	33	32	29	23	22	21	22	26	27

Fig. 2.

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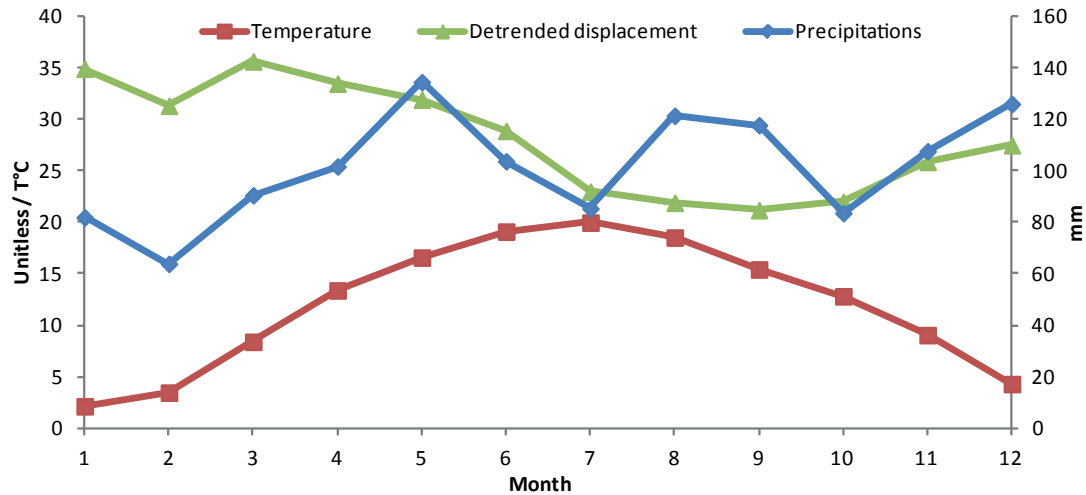


Fig. 3.

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