Replies to the comments of the Anonymous Referee #2

The work describes the use of different soil moisture estimates for the initialization of a relatively simple conceptual event-based hydrological model. The model soil moisture routine is based on the SCS Curve Number approach; the runoff propagation routine is based on the geomorphological unit hydrograph. Observations from the 109 km2 wide Rafina catchment, in Greece, are used to drive the model and to evaluate the initial soil moisture estimates for fifteen rainfall-runoff episodes characterized by generally low flow peak magnitude. Four different methods are used to provide soil moisture estimates: two remote sensing products, the ECMWF-based soil moisture reanalysis, and ground-based soil moisture measurements carried out at 25 cm depth. These estimates are supplemented with soil moisture estimates obtained at the start of the events by using a continuous hydrological model. The novelty of the work is represented by the development and verification of a modeling chain that permits the incorporation and the evaluation of external soil moisture estimates. The work is very interesting, significant and well suited to the readership of HESS. However it needs a careful reorganization and attention to a number of issues to be acceptable for a major scientific journal.

Reply: We thank the referee for her/his valuable comments and for getting the relevance and the importance of the work. In the revised version of the paper, we will address all the referee's issues in order to make the paper clearer and better structured. In the sequel, we will provide the reply (in red) to each comment (in black); in blue, we will report the parts of the manuscript that serve for clarifying our replies.

1. The overall purpose of the paper is to provide soil moisture estimates at the start of flood events for flood prediction and flood risk management. However, the data used in the manuscript concerns low-to-moderate rainfall-runoff events. For the selected events, the max peak discharge is around 40 m3/s, i.e. 0.4 m3/(s km2), with 8 events less or equal than 6.7 m3/s. These magnitudes should be contrasted with the intensities of flood events of some relevance for risk management in the region (as a reference, the 500-yr return period peak discharge is estimated around 250 m3/s (Karagiorgos et al., 2012 and references therein)). The gap between the 'real' flood conditions in the basin and the analyzed rainfall-runoff events is totally understandable: the period considered in the study (from March 2009 to December 2012), was probably too short to capture significant flood events. Nevertheless, the gap should be identified by the authors, and the implications should be discussed. On the one hand, I think that the value of the technical analysis is not affected by the use of low-magnitude events, since the impact of the initial soil moisture conditions is (generally) expected to be more important for low magnitude events and to decrease with the magnitude of the event (however, Marchi et al., 2010, identified that the

impact of initial wetness condition is still important for extreme flash flood events). On the other hand, it should be borne in mind that some assumptions used in the modelling chain may be less realistic when low-magnitude events are considered. This is the case of the lumped approach and the rainfall estimation procedure: small scale events are usually more affected by rainfall spatial variability than extreme events are. As a further and necessary step, the authors should identify how the findings from this analysis can be extrapolated to more severe events.

Reply: The need to show the performance of different kind of soil moisture indicators at the time of the preparation of the paper forced us to restrict the analysis to a period in which all of them were available, e.g. AMSRE is not more available after October 2012. At the same time, we struggled to extend our analysis period in order to capture as many flood events as possible (especially the bigger ones). Hence, we decided to not include events after December 2012, such as for instance, a large event (the largest among the ones considered) occurred on 21 February 2013.

To show that our approach is robust and works well also for high magnitude floods we will include here and in the revised version of the paper (as independent event) the results obtained in validation for such an event which has recorded a total peak discharge of about 150 m^3/s (i.e. about three times the the maximum recorded in the previous analysis).

To run the model we used the parameters obtained by the calibration against the first eight events as described in Section 4.3.2 of the paper. As indicator of soil moisture prior to the flood events we used soil moisture data from the Advanced Scatterometer (ASCAT, pixel 1999295) and in situ soil moisture recorded at Pikermi station. Due to the lack of rainfall data in this period for Kantza and Spata stations, only 4 rain gauges were used for the analysis (Pikermi, Penteli, R400 and R600, please refer to Figure 2 of the paper to visualize them).

Figure 1a and b show the simulated and the observed discharge obtained for the event of 21 February 2013 using in situ and ASCAT soil moisture indicators, respectively (ERA-LAND indicator results' will be provided in the revised version of the paper since we need to retrieve data for this period). As it can be seen results are very good giving NS equal to about 0.8 an error in peak discharge below 15% for both the indicators. This is relevant considering that the calibration was carried out on low-to-moderate flood events.

Considering discharge estimations from previous studies it has to bear in mind that data for the catchment are relatively recent (we did not find any observations longer than 8 years) and a statistical analysis to extrapolate the value of the peak discharge for high return periods (such as the one carried out in Karagiorgos et al., 2012) must be handle with care.

Concerning the effect of the spatial variability of the precipitation on low to moderate rainfall-runoff events, we know that this may affect the result of the analysis. In our study we have presented the worst possible situation (mean areal rainfall calculated by the Thiessen polygon method) obtaining to our point of view satisfactory results. Nonetheless, the model is very well suited to be extended to different mean area rainfall calculations and also to be modified to take into account the spatial variability of the precipitations in a semi-distributed manner like the MISDc model presented by Brocca et al. 2011.

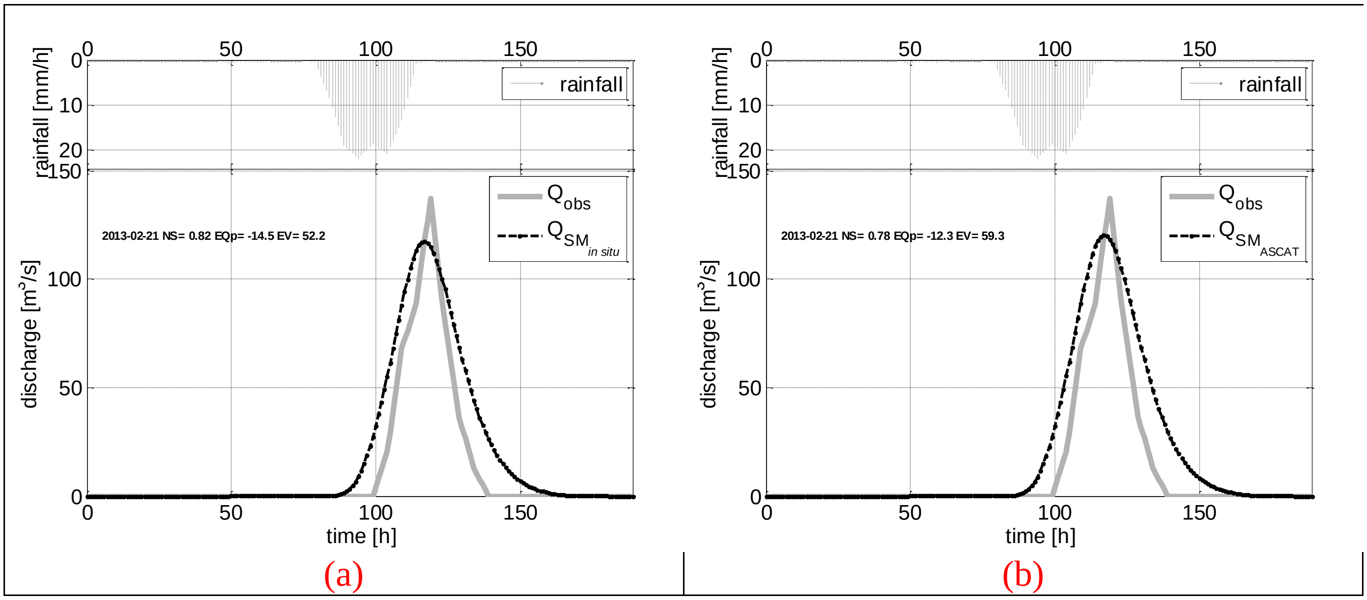

Figure 1: Observed (Qobs) and simulated (Q_{SM_obs}, Q_{SM_ASCAT}) discharges obtained in validation for the event of 21 Febraury 2013 using soil moisture from in situ data (a) and from the advance scatterometer ASCAT (b).

2. The initial soil moisture status is not the only subsurface water state variable which may affect the hydrologic response. The water content of the bedrock system may be relevant as well, particularly in Mediterranean catchments where partially karstified aquifers are common (karst areas make up more than half of the Mediterranean drainage basin – Ganoulis 2003). This is the case of the Rafina basin, where geological formations such as limestones and shists, prone to fracturation and cave formations, form a good portion of the basin. It is likely that model-based soil-moisture simulations account for an overall 'wetness state' of the basin (including both soil and bedrock moisture content), whereas remote-sensing – based soil moisture estimates reflects more properly only the moisture status of the soil layer. This ambiguity is particularly relevant for the CN-SCS model used here, which does not consider the groundwater contribution to the runoff formation. The authors should identify and clarify adequately this ambiguity.

Reply: This is a good point that allows us to clarify an important aspect of the paper. Indeed, we agree with the referee that the water content of the bedrock system may have an influence on the rainfall runoff transformation. In our study, the use of the moisture status of the soil layer, i.e. the one retrieved by satellite, in situ or from reanalysis, does not want to describe exactly the overall 'wetness state' of the system from the surface to the bedrock, but rather it is an "indicator" or proxy of wetness state of the catchment (Beck et al. 2010, Brocca et al. 2009a, 2009b). We will add some clarifications in the revised version of the paper.

3. One main point in the modeling chain is the integration of two different models: one (termed RR) is used to describe the flood processes, whereas a continuous hydrological model (termed SWB) is used for the simulation of the hydrological cycle. There are both presentation, practical and theoretical issues which must be accounted for here. PRESENTATION: The presentation of the two models is bad and ambiguous, making it hard to understand how the two models are considered and linked. The ambiguity starts with Section 3.1, where a event-type flood model is presented as a continuous model. To this reviewer, a continuous model is a model which is able to account for the soil moisture balance over a long-term period, and which is able to describe the relevant hydrologic physical processes such as evaporation, transpiration and groundwater flow. This is certainly not the case for the model presented in Section 3.1. The ambiguity grows with Section 3.3, where the SWB model is presented. The SWB includes five parameters to be estimated (i.e., calibrated). Apparently, the SWB model parameters are estimated based on comparison with FDR soil moisture measurements. This is reported in a cursory way in Section 4.1. The part concerning the model calibration should be moved to Section 3.3. PRACTICAL ISSUES: 1. At Section 4.3, it is said that the SWB model parameters are optimized by using the discharges measured in Rafina. How is this calibration carried out, with a model lacking any runoff propagation routine? Moreover, this is conflicting with the model parameter calibration described in Section 4.1. THEORETICAL ISSUES: The authors should clarify how the model states obtained from SWB model can be used to surrogate the value of S in RR model, in view of the different model structures and model calibration procedures. The manuscript doesn't provide any detail on this step.

Reply: As the presentation of the paper seems to not be clear, we will improve it according to the referee suggestions. In particular, we will remove the SWB model from the methodology and from the results and add the MISDc model (Brocca et al. 2011) to maintain a baseline for comparing our approach with a continuous model. In the MISDc model, the component simulating the soil moisture is exactly the SWB model. In this manner, the content of the paper will not differ from the original one but its presentation will be much clearer.

Eventually, in the methodology we will have the description of our model (improved), the description of the MISDc model, the exponential filter and the performance scores. In the results, we will add the outcomes of the MISDc model as a baseline for assessing the capabilities of our model. Moreover, we will remove Figure 3a (SWB soil moisture against in situ data) to avoid misleading. Finally, we will add the results in validation of the event of February 2013 (described at Point 1) as independent event.

Concerning the "continuous" term given to our model we believe that it is valid since the model does account for the soil moisture balance over a long term period, but the soil moisture rather to be modeled (e.g., from evapotranspiration, infiltration and drainage data), it is obtained directly from observations. This is somehow the novel aspect of our approach.

In other words observed soil moisture is the outcome of the mentioned hydrological processes and somehow it is able to quantify the temporal evolution of such quantities. Actually, our method represents a novel technique for continuous modelling of flood events and this may generate misunderstandings. To extrapolate, we can see our model as an assimilation technique of the soil moisture into a continuous model in which the observed soil moisture is considered error free (i.e. $\sigma^2=0$, gain parameter G=1, Brocca et al. 2010) and its value is directly inserted in to the model. In the revised version of the manuscript, we will attempt to better clarify these aspects and the novelty of the approach.

4. The above “Presentation” ambiguities are not sorted out with the Answer provided by the Authors to Reviewer1 (Point 9, 10 and 11 in the Interactive Comment). In that answer, the Authors continue to present RR as a continuous model, which is not the case. To this reviewer, RR is an event model able to exploit soil moisture estimates from external sources.

Reply: please see reply to point 3.

5. Representativeness of the single site FDR soil moisture measurement. 25-cm depth, FDR measurements of soil moisture from a single site are used to supply ground based catchment-scale soil moisture estimates. These estimates are contrasted with satellite measures representative of different soil depths and characterized by different support area. The obvious jump of scale and the relevant implications should be adequately commented in the manuscript.

Reply: Many studies have shown that soil moisture measurement at single locations reflect the temporal variability of the soil moisture at catchment scale (Vachaud, 1985). The influence of the soil moisture measurements depth on rainfall runoff transformation is taken into account by using of the Exponential filter proposed by Wagner et al. (1999) and Albergel et al. (2012) as explained in section 3.2 of the paper. We will clarify these issues in the revised version of the manuscript.

Details: There is a large number of instances which are in needs of improvement and correction. Most of these have been already identified by Reviewer 1.

Reply: we will correct all instances highlighted by both referees in the revised version of the paper.

References

Albergel, C., de Rosnay, P., Gruhier, C., Muñoz-Sabater, J., Hasenauer, S., Isaksen, L., Kerr, Y., Wagner, W. 2012. Evaluation of remotely sensed and modelled soil moisture products using global ground-based in situ observations. Remote Sensing of Environment, 118, pp. 215–226.

Beck, H.E. et al., 2010. Improving Curve Number Based Storm Runoff Estimates Using Soil Moisture Proxies. IEEE Journal of selected topics in applied earth observations and remote sensing, 2(4), pp. 250–259.

Brocca, L, Melone, F, Moramarco, T & Singh, V.P. 2009a. Assimilation of Observed Soil Moisture Data in Storm Rainfall-Runoff Modeling. Journal of Hydraulic Engineering, (2), pp. 153–165.

Brocca, L, Melone, F & Moramarco, T, 2009b. Antecedent Wetness Conditions based on ERS scatterometer data in support to rainfall-runoff modeling. Journal of Hydrology, 364(1-2), pp.73-86.

Brocca, L., F. Melone, T. Moramarco, W. Wagner, V. Naeimi, Z. Bartalis, and S. Hasenauer. 2010. “Improving Runoff Prediction through the Assimilation of the ASCAT Soil Moisture Product.” Hydrology and Earth System Sciences 14 (10) (October 12): 1881–1893. doi:10.5194/hess-14-1881-2010.

Brocca, L., Melone, F. & Moramarco, T., 2011. Distributed rainfall-runoff modelling for flood frequency estimation and flood forecasting. Hydrological Processes, 25(18), pp. 2801–2813.

Coustau, M., Bouvier, C., Borrell-Estupina, V., & Jourde, H. 2012. Flood modelling with a distributed event-based parsimonious rainfall-runoff model: case of the karstic Lez river catchment. Natural Hazards and Earth System Science, 12(4), pp. 1119–1133. doi:10.5194/nhess-12-1119-2012.

Vachaud, G, A Passerat De Silans, P Balabanis, and M Vauclin. 1985. “Temporal Stability of Spatially Measured Soil Water Probability Density Function.” Soil Sci. Soc. Am. J. 49, 822–828.

Wagner, W., Lemoine, G., & Rott, H. 1999. A Method for Estimating Soil Moisture from ERS Scatterometer and Soil Data. Remote Sensing of Environment, 4257(99). pp. 191-206.