Answer to referee #2

We first wish to thank the anonymous referee #2 for his feedback and his agreement on the interest and originality of the study.

We present in this paper the use of a variance based sensitivity analysis method applied to 10 large flash floods for 6 headwater catchments covering various physiographic conditions. A distributed hydrological model adapted to the simulation of Mediterranean flash-floods is used and the temporal evolution of the sensitivity factors of the computed discharge to 5 parameters during the various phases of flood events is analysed.

We hope that English corrections made thanks to reviewers' comments will help to make the paper more intelligible.

Answer to general comments:

1) We agree that our approach is a local sensitivity analysis which aims at proposing a framework and analysing temporal dynamics of parameter sensitivity (TEDPAS) for a functioning point in the parameter space of an event hydrological model. The effect of parameters variations on model outputs are analysed within large samples of parameter sets. That kind of method is basically not an OAT sensitivity analysis as defined by Saltelli and Annoni 2010.Variance based methods are instead part of the practices Saltelli and Annoni (2010) recommended as an alternative to OAT analysis.
   Concerning the analysis of dependencies between parameters, as stated in the paper and fro example in [*Ratto et al.*, 2007a; *Ratto et al.*, 2007b] S_{is} are scaled between 0 and 1 by definition. Indeed the formulation of each summand of the HDMR (including second order variances) is a conditional variance, that is to say the integral of the square of a real function (cf. eq. 4), which implies the positivity of V_{ij}'s.

   Concerning the locality (in the parameter space) of the proposed analysis, global sensitivity analysis of MARINE model has already been tested (Roux et al., 2011). The present paper investigates the other types of information that a temporal sensitivity analysis can provide.

2) We agree, and calibration/validation of MARINE model for this study has been explained in the paper. Calibration for a given catchment is performed over several flash flood events with an optimization technique considering different starting points in the parameter space, as detailed in the revised manuscript. We think that using several flash flood events to constrain parameter values helps to reduce equifinality problem. But calibration for hydrologic models is still an open question especially difficult for event models and extreme catchments' behaviours such as flash floods.
   p. 1388, lines 8-10. Sentence rephrased in: "Catchment parameter sets that will be used in this paper are given in Table 2."
   Table 3 and sentences added to explain calibration methodology: "For each catchment, model calibration is performed by estimating a parameter set over several flash flood events (Table 3), i.e. a cost function equals to 1-Nash is minimized over multiple flood events (called global Nash hereafter). The minimization technique is a BFGS (Broyden–Fletcher–Goldfarb–Shanno) algorithm considering multiple starting points in the parameter space. The validation is performed on other available flash flood events and efficiencies are given in Table 3." We do not pretend to have reached "the best parameter sets" for these catchments, the word optimal needing to be defined in function of the modeling goals, especially if modeling (and data) uncertainties and parameter values are considered variable in time. Nevertheless,

performances of the model on the events considered in calibration and in validation are rather high over the six catchments of interest (Table 3). Performance decrease is slight for the whole catchment set from calibration to validation with mean Nash values of 0.86 and 0.7 respectively (Table 3).

We agree that rainfall to runoff modelling for large validation events in Mediterranean context is not easy regarding the highly non-linear mechanisms involved in catchment responses. MARINE model is especially designed for flash flood prediction and good performances obtained for these catchments-floods are encouraging. Yet we would like to point out that the aim of this paper is not to test the predictive performances of the model, which would require a larger set of events under various conditions.

Answer to minor comments:

1) We agree about the complexity of the runoff generation process and we are conscious of the problems involved in their modelling especially scales problems. MARINE model has been built with a mechanistic approach and equations. The expression "physically based" was used in opposition to fully conceptual and empirical models. Replaced by: "process oriented".

2) OK, abstract line 5 rephrased in : « Characterizing catchment's response during flash flood events may provide a new and valuable insight into the dynamics involved for extreme catchment response and their dependency on physiographic properties and flood severity."

3) Mathematical developments in part 2 have been explained. p1382, line 5, "factors" and "inputs" replaced by "…model parameters …. k model parameters normalized by their variation range." The g functions are used in the HDMR decomposition (eq. 1) ([*Saltelli et al.*, 2010; *Saltelli et al.*, 2000]) and to write a demonstration of HDMR unicity in case of orthogonality and zero mean of g functions (cf. eq. 1, 2 and explanations). The aim of the State Dependent Parameter method used in this paper for partial variances calculation is to avoid double integrals calculations. Page 1384, lines 4-5, "The estimation of partial variances could be very expensive with brute-force methods but a shortcut was proposed by Sobol' to reduce the calculation of the double loop integrals of Eq. (4)." That is why we cannot give an expression of g.

   P.1384, L.15: Details of random balance design, gaussian process emulators or polynomial chaos expansion are not of interest for the scope of this paper. Citations have been kept for the reader interested in these alternative techniques. Sentence replaced by: However, several alternatives techniques were introduced recently allowing the estimation of S_i's and low interactions effects (up to order 3) for a computational cost independent from k (i.e. equal to N the sample size) (RBD-FAST from Tarantola et al. (2006); Mara, 2009; Sacks et al., 1989; Storlie and Helton, 2007; Oakley and O'Hagan, 2004; Sudret, 2008; Crestaux et al., 2009).

   Notion of metamodel explained. p.1384, line 16. Sentences rephrased and added: "The method used in this paper is the State Dependent Parameter metamodelling method (Ratto et al., 2007a) which is based on recursive filtering and smoothing estimation to build an approximation of the computational model. Ideas and tools from signal processing and time series analysis are used to estimate the terms in the ANOVA-HDMR decomposition using a special recursive fixed interval smoothing algorithm that estimates the parameters in a State-Dependent Parameter (SDP) formulation of the input–output mapping (Ratto et al., 2007a).

4) English corrections made thanks to reviewer comments.

References:

Ratto, M., A. Pagano, and P. Young (2007a), State Dependent Parameter metamodelling and sensitivity analysis, Computer Physics Communications, 177, 863-876.

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Saltelli, A., P. Annoni, I. Azzini, F. Campolongo, M. Ratto, and S. Tarantola (2010), Variance based sensitivity analysis of model output. Design and estimator for the total sensitivity index, Computer Physics Communications, 181, 259-270.

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