Authors would like to thank the anonymous reviewers for their interesting questions and remarks and also for providing a bibliographical complement. Please find enclosed our responses.

Reviewer n°1

General comments

The following part was added: Several optimization approaches have been proposed in the literature since the early work of Bras and Rodríguez-Iturbe (1976) and Delhomme (1978) who proposed a methodology of network design based on the minimization of the mean areal kriging error variance. The adoption of geostatistical methods for rainfall network sizing and augmentation was also performed by Pardo-Igúzquiza (1998). In Delhomme (1978), the optimal location of rain gauges was identified using a technique called the fictitious point method while in Pardo-Igúzquiza (1998) an automatic optimization technique namely simulated annealing was adopted. Barca et al. (2008) provided a methodology for assessing the optimal location of new monitoring stations within an existing rain gauge monitoring network. The methodology used geostatistics and probabilistic techniques (simulated annealing) combined with GIS. A method composed of kriging and entropy that can determine the optimum number and spatial distribution of rain gauge stations in catchments was proposed in Chen et al. (2008). Chebbi et al. (2011) have considered mono objective criteria assuming 1 hour rainfall intensity interpolation and erosivity factor interpolation and using one single extreme rainfall event to conduct the analysis. Rainfall quantities retained in previous studies were mainly taken in a deterministic way. Effectively, a single rainfall pattern was selected for which the average kriging variance was minimized to achieve the best new raingage locations (Delhomme (1978), Pardo-Igúzquiza (1998), Chebbi et al. (2011)). In the present study, it is aimed to find out new observation locations using a collection of rainfall patterns or rainfall auxiliary variables each characterised by its probability of occurrence. Because robust optimization is an approach which can deal with the uncertainty in optimization problems by computing a solution that can cope with possible different scenarios (Mulvey et al., 1995, Bai et al., 1997, Beyer and Sendhoff, 2007), we claim that a robust network augmentation framework is proposed here.

Specific comments

P14211 line 19: Yes we mean weak correlation. It has been changed.

P 14211 line 23. It is the variance of estimation error. It was corrected in the text.

P 14212 deriving a(T) using b(T) as external drift contributes to decrease the variance of a(T) estimation error. Because the number of “observed” a(T) is small, we believed that the use of the information about b(T) may help to decrease the uncertainty about the interpolation of a(T). b(T) was interpolated according to a grid and was introduced as external drift.

P14212. The formulation was modified in order to take into account your remark which was also addressed by reviewer 2 (point 9 in the following):

To evaluate the mean spatial kriging error variance over the study domain, a grid mesh with a resolution of 4 km was used. The optimization problem consists of minimizing the objective function expressed by:

$$\text{Min} \quad \sum_{i=1}^{NT} \omega(T=T_i) * \left(S(T=T_i) - S_{ref}(T=T_i)\right)^2 \qquad (8)$$

$\sum_{i=1}^{NT}\omega(T=T_i)=1$; $\omega(T=T_i)$ as indicated in (Eq.7) and S_{ref} $(T=T_i)$ being the value of the standardized mean spatial kriging variance obtained for every return period T_i independently of the other return periods. It is taken as reference.

In addition, standardization of the mean spatial kriging variance is obtained by using the interquartile range of *a(T)* kriging error variance map:

$$S(T=T_i)=\left(\sum_{i=1}^{n}\left(\sigma_{i(a(T=T_i)))}\right)^2/n\right)\Big/F(T=T_i) \quad (9)$$

Where $(\sigma_{i(a(T=T_i)))})^2$ is the variance of kriging errors of $a(T=T_i)$ at the computing node i depending on locations of stations and n is the number of grid nodes.

$$F(T=T_i)=\left(\sigma^2_{75\%(a(T=Ti))}-\sigma^2_{25\%(a(T=Ti))}\right) \quad (10)$$

$\sigma^2_{75\%(a(T=T_i))}$ is the 75% percentile of the pattern of the variance of kriging errors of $a(T=T_i)$

$\sigma^2_{25\%(a(T=T_i))}$ is the 25% percentile of the pattern of the variance of kriging errors of $a(T=T_i)$

This objective function is subjected to domain constraints expressed by the set of possible locations for the stations (as such the solution space is defined).

P 14213 line 10. By “all cases” we mean all the solved optimization problems (two horizons with four different target networks (+25%; +50%; +100%; +160%) of augmentation. It has been changed in the text:

In all cases (for the two horizons with the four different scenarios of network augmentation (+25%; +50%; +100%; +160%), the minimization problem is solved using a simulated annealing algorithm (Kirkpatrick et al., 1983).

P14213 Line 10

The space of feasible solutions is constituted by every candidate network belonging to the study area. The problem was solved without constraints on the objective function but with the constraint that any new location must belong to the prefixed candidate solutions. The objective function works using simulated annealing in order to select among the candidate solutions, stations that minimize a weighted sum of squared deviations between two standardized mean error variances. The weights are ω.

In line 21 of page 14214, what do you mean by “overrun”?: exceedance

In the abstract and the introduction you promised a robust design. Please add a section that demonstrates that your design method (not just its outcome in this case) is robust. In the results section we have added:

In a previous paper (Chebbi et al., 2011), mono objective criteria have been considered assuming 1 hour rainfall intensity interpolation and erosivity factor interpolation and using one single extreme rainfall event to conduct the analysis. The comparison of previous results with the present study highlights that the mean spatial kriging variance in the case of the mono objective criterion is lower or equal to that obtained in the case of the robust optimisation. Nevertheless, the essential advantage of the robust optimization lies in the fact that it allows to overcome the problem of using one single rainfall event and yields networks which work ‘adequately’, when considering various extreme events with different return periods.

Technical corrections

P14207, line 26 . Yes thank you.

P14208 line 14. We mean that this network is scarce.

P14208 line 16. The size of the initial network is referred to the number of stations. We replaced “size” by “number of stations”.

P14209. Yes by adjusted parameters we mean *a(T)* and *b(T)* of IDF curves of Eq. 1. “of Eq. 1” is added so that the sentence becomes: the parameters of adjustment of the Intensity-Duration-Frequency (IDF) curves (Koutsoyiannis et al., 1998) are proposed as alternative (parameters *a(T)* and *b(T)* of Eq. 1)

P14209. Montana model is a power law model but it is commonly known as Montana model in the hydrologic literature. We already stated that it is a power function of the duration. We added Burlando and Rosso (1996)

P14210 line 3: a reference is added for geostatistical approaches

P14210 line 9. Yes it is experimental semi variogram. The term experimental was added. Thank you. A reference to Chilès and Delfiner 1999 was added

P14211 line 6: “digital numbers” has been replaced by “measurements”

P14212 Eq.8: Yes thank you the parenthesis and the square symbols were not adequately reported. However Eq. 8 was rewritten.

P14214 line 3. Yes we mean no pattern by saying “erratic”

P14217 Eq. A5, the “/” has been replaced by “|”