

# Estimating strategies for multiparameter Multivariate Extreme Value copulas

G. Salvadori and C. De Michele

## Reply to Referee 1

The Authors wish to express their gratitude to Referee 1: her/his illuminating comments gave us the possibility to properly fix several questionable issues, and improve the overall quality of the paper. Below please find our point-to-point reply to the Referee's objections.

1. Referee 1 writes: "The authors based their work on the concept of geometrical distance between stations...", and lists a few references explaining why "the geometrical distance between catchments does not completely explain the dependence of the hydrological behaviour of catchments".

We agree with the objection of Referee 1. This gave us the possibility to generalize the techniques outlined in the previous version of the paper. In turn, the fitting strategies outlined in the revised version do not necessarily use the geometrical distance as a criterion to choose the source of information. More particularly:

- The 1-MEV approach is now named "The single station approach", and the new strategy is described as follows: "The first approach we propose for the estimate of the parameters of interest consists in using the information drawn from a single station at a time. Practically, for each of the available gauge stations  $S_i$ 's, a suitable "companion" station  $S_j = S_{j(i)}$  is identified, possibly according to specific physio-geomorphological conditions and/or hydrological constraints...".

Also, the following final comment/warning is added: "We stress that the use of the Euclidean distance as a criterion for choosing the source of information (i.e., adopting a *nearest neighbor* principle) may not always be the most advisable strategy. In fact, it has been shown (see, e.g., GREHYS (1996); St-Hilaire et al. (2003); Merz and Bloesch (2004); Gal  a and Canali (2005); Wagener and Wheeler (2006); Ouarda et al. (2008); Shu and Ouarda (2008)) that the geometrical distance may not completely explain the dependence structure of the hydrological behavior of catchments: indeed, several are the physio-geomorphological factors that may influence it. Therefore, the validity of the nearest neighbor approach should be tested out by carefully checking the practical case study under investigation."

- The new c-MEV approach is described as follows: "The 1-MEV approach adopted in the previous Section only exploited the information drawn by a single station. This strategy can be generalized: in fact, a full cluster of companion gauge stations (instead of just one) may be chosen as a source of information. Clearly, the cluster can be fixed according to specific physio-geomorphological conditions and/or hydrological constraints (e.g., by identifying a homogeneous region, or a basin of influence)."

The practical description of the new method introduces further generalizations: "Let  $S_i$  be the  $i$ -th station, and let  $\mathcal{C}_{m_i}^{(i)}$  be a cluster of  $m_i$  stations "pertinent" to  $S_i$ , with  $1 \leq m_i < d$ . Clearly, the choice of  $m_i$ , as well as the selection of the set of relevant companion stations belonging to  $\mathcal{C}_{m_i}^{(i)}$ , can be made dependent upon specific basin characteristics, and changed when considering different stations."

In the Case Study section the minimum Euclidean distance is adopted in the 1-MEV approach as a criterion for choosing the source of information: however, it is clearly pointed out that such a choice “is motivated by illustrative purposes only”. Similarly, also the selection of the four clusters  $\mathcal{F}_2 = \{S_2, S_9, S_{10}\}$ ,  $\mathcal{F}_6 = \{S_6, S_9, S_{10}\}$ , and  $\mathcal{F}_9 = \mathcal{F}_{10} = \{S_9, S_{10}\}$  used in the c-MEV approach, and having different sizes, is motivated by illustrative purposes only.

2. Referee 1 writes: “S2 is upstream of S9. S9 may depend on S2; the opposite is difficult to prove. The approach of the authors does not take into account the position of station in river (upstream-downstream).”

The target of this paper is the introduction of fitting techniques for multivariate copulas. The choice of the particular model used for illustrative purposes is of minor relevance. However, the objection of Referee 1 gives us the possibility to emphasize an important point: the copula used is non-exchangeable. This means that the dependence between, say,  $S_i$  and  $S_j$  is not symmetric. In turn, the following sentence is added in the revised version of the paper: “From a practical point of view, this latter feature [non-exchangeability] may provide a consistent model of the asymmetric relationship between upstream and downstream river stations, viz. the upstream stations may “influence” the downstream ones, but the converse may be difficult to prove.”

3. Referee 1 writes: “In spite of the fact that the authors mentioned that no design of actual structures is involved, their example shows the opposite.”

The meaning of our sentence has been misinterpreted: this is our fault, for we are not English mother-tongue, and evidently the interpretation of our statement turned out to be ambiguous. Our intention was simply to say that no practical project of actual hydrological works is undertaken in our paper: we are only interested in describing the fitting methods, and no design aims are considered in this study. In order to make the sentence clear, it has been rewritten as follows: “However, here the target is not to provide an ultimate extreme flood model, and no practical project of hydrological works is undertaken. Instead, our point is only to show, in a relatively simple case, how the techniques outlined above can be used in practice: in other words, this is a methodological paper.” In addition, we want to specify that we are well aware that the Spey river is interested by regulated works. In turn, the selection of the gauge sites has taken into due account this issue: in fact, the stations considered are all located downstream the last regulation, and thus all the sites are similarly equally “disturbed”.

4. Referee 1 writes: “The authors concluded that the suggested techniques are physically based.”

As above, this is our fault, for we are not English mother-tongue. Referee 1 clearly explains that “The approaches physically based are based on phenomenological equations. They apply to systems which functioning can be described in a complete and predictive way by a set of physically laws.” Evidently, this is not our case: we misinterpreted the meaning of the word “physically-based”. For these reasons, throughout the revised version of the paper we discarded the adjective “physically-based” when making reference to our techniques.