Hydrology and Earth System Sciences Discussions

Interactive comment on "Evidences of relationships between statistics of rainfall extremes and mean annual precipitation: an application for design-storm estimation in northern central Italy" *by* G. Di Baldassarre et al.

G. Di Baldassarre et al.

Received and published: 27 March 2006

GENERAL COMMENT

First of all, we would like to thank the Editor, Associate Editor and Reviewers for doing excellent work and providing very useful observations and comments, which truly helped us in improving the overall quality of the presentation of our work. The revised manuscript that we are going to resubmit for possible publication is the proof of our deep appreciation for the useful and constructive indications and suggestions provided by Reviewers. We detail in the remainder of our reply how we incorporated all Reviewers' suggestions and comments in the revised manuscript, which, in our opinion, has

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an improved readability and represents an original contribution to the comprehension of the statistical behaviour of rainfall extremes for the study area. A theme of both reviews is the supposed strong similarity between our manuscript and the study by Brath et al. (2003). Prior to the detailed discussion of Reviewers' comments, we would like to remark here the differences and improvements between our study and the analysis described in Brath et al. (2003). By following an approach originally proposed by Alila (2000), Brath et al. (2003) identify a set of generalized depth-duration-frequency equations for the estimation of design storms for storm duration from 1 to 24 hours and test the equations' reliability through a jack-knife cross-validation. We believe that, with respect to previous studies (e.g., Schaefer, 1990; Alila, 1999; Brath et al., 2003), our manuscript presents new data, new concepts and ideas and different tools. For the first time in this study area, our study utilises an updated and significantly enlarged dataset with respect to Brath et al. (2003), which includes sub-hourly rainfall extremes (storm duration of 15 and 30 minutes) and is presented and analysed for the first time (new data). This is acknowledged by one Reviewer (see Bernardara, 2005, p. S1078). We model the relationship between statistical properties of rainfall extremes and mean annual precipitation (MAP) using a Horton-type curve (new concepts and ideas). We show that the curve is statistically significant for all duration considered in the study through an original extensive and objective Monte Carlo simulation experiment that we specifically designed for this purpose, as acknowledged by one Reviewer (see Bernardara, 2005, p. S1079). On the basis of these relationships, we develop a regional model for estimating the rainfall depth for a given storm duration and recurrence interval in any location of the study region (different tool). Perhaps the first version of our manuscript did not present these original contributions clearly enough. Therefore, the changes incorporated in the revised manuscript mainly aim at improving the description of the physical reasoning underlying the development of the analysis, addressing in particular the identification of climatically homogeneous regions. Also, we put more emphasis on the description of the model developed and on the technique used to assess his reliability as suggest by a Reviewer (see Bernardara, 2005, p. S1078). Fi-

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nally, we included an additional analysis in the revised manuscript (described in a new section 5.3) in order to quantify the sensitivity of regional L-Cv and L-Cs estimates for ungauged sites. In particular, we performed a jack-knife resampling procedure that enabled us to quantify the uncertainty of regional rainfall quantiles for T = 100 and 200 years. These further analyses show that the estimation of the index-storm is the critical step for the application of the proposed regional model to ungauged sites.

The remainder of our reply, after a summary of the revised manuscript structure, addresses the comments raised by Dr. Younes Alila.

REVISED MANUSCRIPT STRUCTURE

We reorganised the revised manuscript as follow:

1 Introduction

2 Index Storm procedure

2.1 Growth factor estimation

2.2 Index storm estimation

3 Study area and locale regime of rainfall extremes

4 Regional model

4.1 Climatically homogeneous pooling-groups

4.2 Empirical regional model for estimating the L-Cv and L-Cs

5 Design storm estimation in ungauged sites

5.1 Application of the regional model

5.2 Index storm and MAP at ungauged sites (section 4.2 in original manuscript)

5.3 Uncertainty of the regional estimates (completely new section)

6 Conclusion

Appendix (Homogeneity test)

REPLY TO REFEREE#2 (Dr. ALILA)

First of all, we would like to point out that most of our comments on Alila's review are included in the interactive comment (Di Baldassarre et al., 2005, S1146-S1154). Nevertheless, we illustrate in this section how the Reviewer's comments and suggestions were incorporated in the revised manuscript. Alila's review is quite critical on several issues. In particular, he questions the suitability of the study for publication in HESS (major comment) and identifies five specific comments as follows: [1] discrepancies of findings for the same study area between this study and a previous study (Brath et al. 2003), [2] misrepresentation of a paper published by Alila (1999), [3] use of incorrect terminology for describing the proposed regional model and [4] limitations in the applicability of the regional model and [5] absence of reference to process understanding and physics of precipitation extremes. Our reply to Alila is structured as follows: in the next section we address the issues associated with the questioned suitability of our manuscript; in the following five sections we address the specific comments listed above.

SUITABILITY OF THE MANUSCRIPT

We already commented on the innovative aspects of our study and the changes incorporated in the revised manuscript associated with this point in section 1 of our reply. Concerning the suitability of the study for a possible publication on Hydrology and Earth Sciences System (HESS), we believe that "HESS is not averse to publishing methods and procedures in hydrological analysis, even if they are not completely new" (Molnar, 2005, p. S1360). Then we would like to remark that we were solicited to submit this manuscript to HESS after the first author won the "Young Scientists' Outstanding Poster Paper (YSOPP) Award" at the last EGU meeting. Nevertheless, we agree that the original version of the manuscript did not present the original contributions clearly

enough. Therefore, the changes incorporated in the revised manuscript mainly aim at improving the description of the physical reasoning underlying the development of the analysis, addressing in particular the identification of climatically homogeneous regions. Also, we put more emphasis on the description of the model developed and on the technique used to assess his reliability as suggest by a Reviewer. Finally, we included an additional analysis in the revised manuscript (described in a new section 5.3) in order to quantify the sensitivity of regional L-Cv and L-Cs estimates for ungauged sites.

REFEREE SPECIFIC COMMENT: "Ědiscrepancies of findings for the same study area between this study and another published manuscriptĚ"

We disagree with the Reviewer on this point. There are no discrepancies between our manuscript and the study by Brath et al. (2003) for the simple reason that the two study areas are different. A comparison between Figure 1 of our manuscript and Figure 1 in Brath et al. (2003, p. 11-3) shows that we excluded the Tyrrhenian Region in our study, and this emerges also from Table 1, which reports the number of raingauges and annual maximum rainfall data. By analysing this table, one can see, for example, that the number of hourly raingauges is 125 in our manuscript, while is 132 in Brath et al. (2003). The Tyrrhenian Region was excluded in our study because this area reveals an atypical behaviour that was already pointed out (see e.g. Castellarin and Brath, 2002 and Brath et al., 2003). Although we agree that analysing this anomaly is interesting in principle, the available rainfall data in the Tyrrhenian Region (7 recording raingauges) do not enable us to carry out a sufficiently accurate analysis. It also would be more correct, from a phenomenological viewpoint, to analyse this area together with the Tyrrhenian coastal Region (Liguria), and this is out of the scope of our study. Maybe some confusion arises from the fact that we wrongly reported (Section 3) that study area is 37200 km2 (as in Brath et al. 2003) while the right size of the study area is 35800 Km2. The revised manuscript reflects this correction (Section 3): "The study area includes the administrative regions of Emilia-Romagna and Marche, in northern

central Italy, and occupies 35800 km2."

REFEREE SPECIFIC COMMENT: "Ěauthors misrepresented a paper published by Alila (1999)Ě"

The Reviewer is right. We wrote "L-Cv can be considered to be independent of the geographic location (or MAP) for d less than 1 hour, with different values for duration equal to 15 and 30 minutes (Alila, 1999)". To be correct, Alila (1999) pointed out that L-Cv values can not be considered to be independent of the geographic location also for sub-hourly duration. We modified quotations in order to correctly describe Alila's work in the revised manuscript, and to better identify congruencies and differences between this manuscript and Alila's findings, in particular we removed the quotation (Section 4.2): "L-Cv can be considered to be independent of the geographic location (or MAP) for $d < 1$ hour, with different values for d = 15 and 30 minutes;" However, it is important to underline that the relationship between sample L-Cv and MAP for our study area and duration less than 1 hour (see Figure 5b) does not point out any significant dependence between the two measures. It is also interesting to remark, regarding this point, that our study refers to a rather dense raingauge network with respect to previous studies: a) the study by Schaefer (1990) refers to Washington State (about 180000 km2) and considers a raingage network with a number of recording raingauges varying from a minimum of 112 for the 2-hour storm duration (on average 1 station every 1605 km2) to a maximum of 316 for the 24-hour storm duration (on average 1 station every 570 km2); b) Alila (1999) refers to Canada (about 10200000 km2) and analyzes the observations collected at 375 hourly raingauges (on average 1 gauge every 27200 km2) and 320 sub-hourly raingauges (on average 1 gauge every 31875 km2); c) our study region has an area of around 35800 km2 and the average network density is 1 station every 91 km2 for daily rainfall data, 1 station every 286 km2, for hourly rainfall data, 1 station every 192 km2, for 30 minutes rainfall data and 1 station every 235 km2 for 15 minutes rainfall data. Finally, it is important to remember again that our results are validated against an extensive and objective Monte Carlo procedure to test the validity of the

assumptions, in order to avoid "blind reliance".

REFEREE SPECIFIC COMMENT: "Ěuse of incorrect terminology for reporting the regional model called "index storm" approachĚ"

The Reviewer is right in the sense that the classical index flood (or index storm if reference is made to rainfall extremes) hypothesis is based on the most restricting assumption that L-Cs and L-Cv "do not vary with location". Nevertheless, since the original model was introduced (see e.g. Dalrymple, 1960) several extensions and evolutions were proposed, which partly relax the fundamental hypothesis of constant statistics (e.g. L-Cv and L-Cs) within a simple geographical homogeneous region. Revised manuscript (section 2): "The classical implementation of the index flood procedure (or index storm if reference is made to rainfall extremes) is based on the most restrictive fundamental hypothesis of existence of homogeneous regions within which the statistical properties of dimensionless rainfall extremes (see e.g., Franchini and Galeati, 1994; Brath et al., 1998) do not vary with location (i.e., coefficients of variation and skewness, or equivalently L-Cv and L-Cs, are constant). Nevertheless, since the original procedure was introduced (see e.g. Dalrymple, 1960) several extensions and evolutions were proposed, which partly relax this fundamental hypothesis. An example is the hierarchical application of the index flood hypothesis, where the statistics of increasing order are constant within a set of nested regions, the larger the order of the statistics, the larger the region (see e.g. Gabriele and Arnell, 1991). Another relevant example of evolution of the original hypothesis is the Region of Influence approach (e.g., Burn, 1990; Castellarin et al., 2001), which adopts the concept of homogeneous pooling groups of sites as opposed to homogeneous geographical regions. We present a regional model that can be considered to be an extension of the index flood model as well. Similarly to what originally proposed in Schaefer (1990) and Alila (1999), we assume that a homogeneous region, within which L-Cv and L-Cs are constant, is a group of climatically homogeneous sites, within which the variability of MAP is very limited."

REFEREE SPECIFIC COMMENT: "Ělimitations in the applicability of the regional mod-

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We agree with the Reviewer (see also Di Baldassarre et al., Interactive comment, S1146-S1154, 2005), and the revised manuscript included these comments at the end of the conclusions (Section 6): "It is important to underline that the proposed regional model was developed through statistical optimisation. Therefore that the model itself can be applied to storm duration from 15 minutes to 1 day and sites located within the study area. A careful application of the regional model should also consider that the model itself was developed for raingauges located below 1500 m a.s.l., while the altitude in the study area can locally exceed 2000 m a.s.l. Finally, the spatial interpolation of rainfall extremes or MAP adopted in our study is unable to reproduce micro-climatic effects such as rain shadow effects, and can only provide an overly simplified representation of differences existing between leeward and windward sides of the same mountain depending of the particular spatial interpolator adopted in the study."

REFEREE SPECIFIC COMMENT: "Ěno reference to process understanding and physics of precipitation extremesĚ"

Concerning this point please refer to our rebuttal on (Di Baldassarre et al., 2005, S1146-S1154). Despite our critical rebuttal, we decided to incorporate some further details on the seasonal regime of rainfall extremes (Section 3): "A regional analysis of the dates of occurrence of short-duration rainfall extremes (i.e. 1 or 3 hours) pointed out significant consistency and a mean timing which varied between the end of July and the beginning of August for the entire study area (Castellarin and Brath, 2002). This is consistent with the observation that in the study area the hourly rainfall extremes are almost invariantly summer showers generated by local convective cells. The dates of occurrence of long-duration rainfall extremes (i.e.,24 hours or 1 day) pointed out less regularity and a mean timing that ranges from the beginning of September to the beginning of November."

REFERENCES

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Discussion Paper

Alila Y.: A hierarchical approach for the regionalization of precipitation annual maxima in Canada, Journal of Geophysical Research, 104, 31645-31655, 1999.

Bernardara P., Interactive comment on Evidences of relationships between statistics of rainfall extremes and mean annual precipitation: an application for design-storm estimation in northern central Italy, Hydrol. Earth Syst. Sci. Discuss., 2, S1078-S1081, 2005.

Brath A., Castellarin A., and Montanari A.: Assessing the reliability of regional depth-duration-frequency equations for gaged and ungaged sites, Water Resour. Res., 39(12), 1367-1379, 2003.

Burn, D. H., Evaluation of regional flood frequency analysis with a region of influence approach, Water Resour. Res., 26(10), 2257-2265, 1990.

Castellarin A., D. H. Burn and A. Brath, Assessing the effectiveness of hydrological similarity measures for flood frequency analysis, Journal of Hydrology, Volume 241, Issues 3-4, 270-285, 2001.

Castellarin A., Brath A., Tecniche di perfezionamento delle stime regionali del rischio pluviometrico (in italian), Atti del XXVIII Convegno di Idraulica e Costruzioni Idrauliche, Potenza 16-19 settembre 2002, Vol. I, 225-236, Ed. BIOS, Cosenza, 2002.

Castellarin A., Brath A., Descriptive capability of seasonality indicators for regional frequency analyses of flood and rainfall, Proceedings of the International Conference on Flood Estimation, CHR Rep. II-17, 429-440, Lelystad, Netherlands, 2002.

Dalrympe, T., Flood frequency analyses, U.S. Geol. Surv. Water Supply Pap., 153-A, 11-51, 1960.

Di Baldassarre G., Castellarin A., Brath A., Evidences of relationships between statistics of rainfall extremes and mean annual precipitation: an application for design-storm estimation in northern central Italy, Hydrol. Earth Syst. Sci. Discuss., 2, 2393-2425, 2005.

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Di Baldassarre G., Castellarin A., Brath A., Interactive comment on Evidences of relationships between statistics of rainfall extremes and mean annual precipitation: an application for design-storm estimation in northern central Italy, Hydrol. Earth Syst. Sci. Discuss., 2, S1146-S1154, 2005.

Gabriele, S., N. Arnell, A hierarchical approach to regional flood frequency analysis, Water Resour. Res., 27(6), 1281-1289, 1991.

Horton RE., Analysis of runoff-plat experiments with varying infiltration capacity. Transactions, American Geophysical Union 20, 693-711, 1939.

Molnar P., Interactive comment on Evidences of relationships between statistics of rainfall extremes and mean annual precipitation: an application for design-storm estimation in northern central Italy, Hydrol. Earth Syst. Sci. Discuss., 2, S1360-S1365, 2005.

Interactive comment on Hydrology and Earth System Sciences Discussions, 2, 2393, 2005.

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