Answer to Reviewer No. 1 of: Extreme runoff response to short-duration convective rainfall in South-West Germany, by Ruiz-Villanueva et al.

March 5, 2012

Introduction

We thank the Reviewer#1 for the positive evaluation of this manuscript, and for having contributed to its improvement. We strengthened the section dedicated to the presentation of the Spatial Moments and revised the Section dedicated to the Radar quantitative rainfall estimation, accordingly with the reviewer's comments. In what follows we provide a point-by-point reply to the reviewer's specific comments.

Comment 1: Radar QPE

Comment 1.1 A big work dedicated to the radar Quantitative Precipitation Estimation (QPE) is briefly summarized in p8. The configuration of the 2 C-band radars with respect to the Starzel catchment is interesting. I understand the data from the 2 radars were merged depending on the computed PIA to produce a single radar QPE (L233 -234). One suggestion:
- it could be interesting to derive QPEs for each radar separately in order to get some idea, from the differences between the 2, on the error of the rainfall inputs and the subsequent impact on the hydrological model results.

Response
We agree with the Reviewer#1 that the large efforts dedicated to the radar rainfall estimation for the Starzel flash flood are not reflected in the section dedicated to the radar QPE. On the other hand, we are going to present in a separate paper the methodology and the results from this radar QPE exercise together with other cases examined in the context of the HYDRATE project. The suggestion from the Reviewer about the individual analysis of each radar and inter-comparison is a very good one, indeed. However, we haven't merged the information from the two radar. Actually, we generally used radar data from Türkheim (TUR) (which is closest to the study basin, 60 km) and used data from the and Feldberg (FBG) radar (located at 90 km from the basin) only when the attenuation impact was too large. Examples are reported in the Appendix to this response, where maps are shown of the rainfall rate from the two radar for two different times (17:15 and 17:40 UTC (i.e. 18:15 and 18:40 CET, corresponding to the hour with the catastrophic rainfall). The location of the two radar antennas is reported in the figures. For 17:45, TUR is more affected by attenuation, and we used data from FBG. Examination of the case at 17:40 reveals that FBG has problems related to the range, and TUR may provide a better estimation. With the exception of a few cases, the rainfall patterns from the two radar look very similar (albeit with important mean differences), enhancing confidence in the rainfall estimation phase.

Comment 1.2 Rather than the cited reference (Delrieu et al. 2000), the good referencing for the mountain reference technique (MRT) is:
Delrieu, G., Caoudal, S. and Creutin, J.D., 1997. Feasibility of using mountain return for the correction of ground-based X-band weather radar data. Journal of Atmospheric and Oceanic Technology, 14(3):368-385.
Serrar, S., Delrieu, G., Creutin, J.D. and Uijlenhoet, R., 2000. Mountain reference technique: Use of mountain returns to calibrate weather radars operating at attenuating wavelengths. Journal of Geophysical Research-Atmospheres, 105(D2): 2281-2290.

In addition, note that Bouilloud et al. (2010) proposed a procedure for radar QPE in the context of post-event surveys for *non-attenuated frequencies* (S-band radars). These authors also performed a case study for a Slovenian rain event where the MRT was effectively implemented for the first time at C-band. The reference of this article is:
Bouilloud, L., Delrieu, G., Boudevillain, B., Borga, M. and Zanon, F., 2009. Radar rainfall estimation for the post-event analysis of a Slovenian flash-flood case: application of the Mountain Reference Technique at C-band frequency. Hydrol. Earth Syst. Sci., 13(7): 1349-1360.

Response
We modified the cited references accordingly with the reviewer's indications.

Comment 2: Spatial moments of catchment rainfall

Maybe everything about the concept of "spatial moments of catchment rainfall" is made clear in the paper by Zocatelli et al. (2010). However, I found the presentation of the concept and the results in the paper under review quite difficult to understand:
Comment 2.1
In L302, I suggest to rephrase as: the so-called "flow distance".

Response:
We agree on this comment and changed the text accordingly.

Comment 2.2
In L306-307, I guess the flow distance is a distance and the runoff travel time is a time, so this sentence doesn't hold…

Response
We re-organised text as follows to answer to the reviewer's comment:
"The use of the flow distance is motivated by the observation that runoff routing imposes an effective averaging of spatial rainfall excess across locations with equal routing time, in spite of the inherent spatial variability. The flow distance may be used as a surrogate for runoff travel time, when hydrodynamic dispersion and variations in runoff propagation celerities can be neglected."
This text clarifies that, under specific circumstances, the flow distance may be used as a surrogate for travel time.

Comment 2.3
Equations (1) and (2) need to be carefully written: in (1) why do you use the absolute value bars for A? I suggest to use đ instead of d_{ave}. In (2), what is g_1? T is not a standard notation for time t?

Response
The Reviewer is right: in Equation (1) the absolute value bars are removed; we substituted g_1, mean value of the flow distances over the catchment, to d_{ave}. The term g_1 is meant to indicate the mean value of the flow distance. The term T indicates the time as a random variable. An appropriate explanation is reported in the revised text.

Comment 2.4
The interpretation of $\delta_2(t)$ and Δ_2 is far from intuitive and I am wondering if these two variables are really useful in the present context (they are apparently not needed for the definition of the "catchment scale storm velocity").

Response

We agree with the Reviewer that the presentation of the terms $\delta_2(t)$ and Δ_2 and their discussion is not essential for the objectives of the work. Actually, we dropped the presentation of the second order statistic in the revised version of the text, in favour of a more extended description of the meaning of the catchment-scale storm velocity concept.

Comment 2.5

It is difficult to recognize in (2) a “storm velocity”; maybe a basic equation would help, in addition to the final result of the calculation.

Response

We introduced the following text before Eq. (2)

“The product δ_1 g_1 represents the distance from the rainfall centroid to the catchment outlet. Examination of the changes in time of this distance permits calculation of an instantaneous catchment-scale storm velocity along the river network, as follows:

$$V_s(t) = g_1 \frac{d}{dt}\delta_1(t) \qquad (2)$$

The concept of the catchment-scale storm velocity defined by Eq. (2) provides a mapping of storm motion over catchment morphology, taking into account the relative catchment orientation and geometry with respect to storm motion. A positive (negative) value of the catchment-scale storm velocity V_s indicates an increase (decrease) over time of the distance from the rainfall of the storm centroid to the outlet, hence upbasin (downbasin) storm movement. In this work, we will not perform any explicit derivative of δ_1 to obtain the catchment scale storm velocity. While Eq. (2) has been introduced to formally represent the concept of catchment-scale storm velocity and how this relates to the first scaled moment δ_1, we will use the methodology introduced by Zoccatelli et al. (2011) to compute the specific values.

Comment 2.6

The rest of the section (L357-387) is hard to understand. The evolution in time of the storm velocity, as displayed in Fig. 7e is quite erratic: wouldn’t it be useful to smooth and/or to display only the values for the significant rain sequences (the 5m/s peak captures the attention of the reader)?

Response

We revised Fig. 7e (now Fig7d) accordingly, by reporting the time series of storm velocity only for the most intense rain sequence.

Comment 2.7

L384-385: this sentence is not understandable to me.

Response

Please see our Response to Comment 2.8.

Comment 2.8

How does the “catchment scale storm velocity” compares with the “storm velocity” as could be derived for instance from standard cross-correlation techniques applied to the radar space-time series?

Response

We introduced the following text in the Introduction to clarify how the "catchment scale storm velocity" compares with the "storm velocity".

"We aim to analyse how the spatial and temporal distribution of the extreme rainfall, and more specifically storm motion, control flood response. This question has been rarely examined with reference to real flood events, essentially because of lack of a methodology relating the space–time properties of rainfall to the drainage basin properties. There are a number of aspects related to storm movement which have an impact on the flood hydrograph. Among these, the direction and the speed of the storm motion with respect to the catchment morphology is probably the most important one (Singh, 1998). To examine in a quantitative way these aspects, we use here the concept of 'catchment scale storm velocity' proposed by Zoccatelli et al. (2011) and based on the Spatial Moments of Catchment Rainfall. These statistics, which build on previous work by Viglione et al. (2010) and correspond in part to the catchment rainfall statistics reported in Smith et al. (2002, 2005), assess the dependence of the catchment flood response on the space-time interaction between rainfall and the spatial organization of catchment flow pathways. Whereas the techniques like cross-correlation applied to the radar images time series may be used to identify the overall storm velocity, the catchment-scale storm velocity provides a map of the overall storm velocity over specific catchment configurations. The catchment-scale storm velocity has therefore an implicit hydrological meaning. Zoccatelli et al. (2011) showed that upbasin (downbasin) velocity are associated to a decrease (increase) of flood peak with respect to an equivalent stationary storm. A finding which is often reported is that the effect of storm motion on flood peak is maximized when storm velocity has similar magnitude as the flow velocity (Singh, 1998)."

Details:

Comment

L21: abstracts should normally not include references:

Response

Done!

Comment

L137: mm/a?

Response

Done!

Comment

L139 and everywhere else: prefer m3s-1km-2 to m3/(s km2); in this specific sentence, the unit discharges should be cancelled or put between parentheses.

L149: reference to Fig. 3 is not relevant in this sentence since there is no frequency information in Fig. 3.

Response

We agree with the Reviewer. We have revised text accordingly.

Comment

Fig. 5 is not really readable with its grey scale; isolines should be used instead.

Response

In this case, use of the isolines makes the figures exceedingly complex to be understood. We prefer to use grey scale.

Comment

It could be interesting to display in Fig. 6 the distribution of the exceedance areas for the QPEs derived for the two radars separately, if available.

Response

Please see our response to Comment 1.1 above.

Comment
L288: woudn't the reference to the KOSTRA methodology be useful in section 2?
Response
Indeed, the reference is already there. We cited KOSTRA project (DWD, 1997) in section 2 to see a detailed explanation of the methodology and (DWD, 2006) in section 4 for the frequency analysis.

Comment
L308: "may be used as"
Response
Done!

Comment
L328: "indicates indicate"
Response
Done!

Comment
L442: "with each other"
Response
Done!

Comment
498: the legend of Fig. 8a (inside the figure) is incomplete
Response
This has been corrected and new figure is reported.

Comment
L554-559: do not forget in the comment of these figures that the hydrological model was calibrated against the IPEC informations.
Response
We revised this sentence as follows:
"For both catchments, the simulated flood peak is included in the range of indirect peak discharge estimates reported on the basis of the post-flood survey, as expected since the IPEC information was used for model calibration."

Comment
L560 and other occurrences: I do not find the term "water balance" appropriate here; rainfall-runoff balance would be more adequate in my view.
Response
We agree. We used instead 'rainfall runoff properties'.

Comment
L545: "and to 20 and 40 mm h-1"
Response
This has been corrected in the text

Comment
L603: I suggest to rephrase as "simulated peak values are substantially lower than the specific values obtained by the IPEC"; same thing in the next sentence. The terms over-estimation and

underestimation suggest that one of the estimation (IPEC or model) is closer to the true value, which is hard to establish.

Response

This has been corrected in the text

Comment

L643-647: for point (iii) I suggest to rephrase as "(iii) the spatial distribution of rainfall within the watershed characterized by the two descriptors delta1 and delta2" and for point (iv) "(iv) the storm dynamics characterized by the catchment scale storm velocity"

Response

This has been corrected in the text

References

DWD: Deutscher Wetterdienst: KOSTRA-DWD-2000. Starkniederschlagshöhen für die Bundesrepublik Deutschland (1951-2000) - Fortschreibungsbericht, Offenbach am Main, Eigenverlag des Deutschen Wetterdienstes, 2006.

DWD: Deutscher Wetterdienst: Starkniederschlagshöhen für die Bundesrepublik Deutschland – KOSTRA, Offenbach am Main, Eigenverlag des Deutschen Wetterdienstes. 1997.

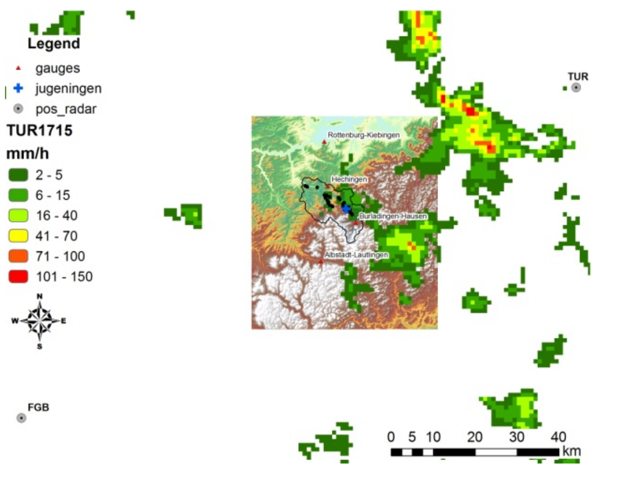
Emmanuel, I., (2011) Evaluation de l'apport de la mesure de pluie par radar meteorologique pour la modelisation pluie-debit de petits basins versants. PhD Thesis, Ecole doctorale SPIGA (Ecole Centrale de Nantes), Thèse préparée à l'Ifsttar de Nantes – Groupe Hydrologie et assainissement.

Singh, V. P. (1998) Effect of the direction of storm movement on planar flow. *Hydrol. Processes* 12, 147–170.

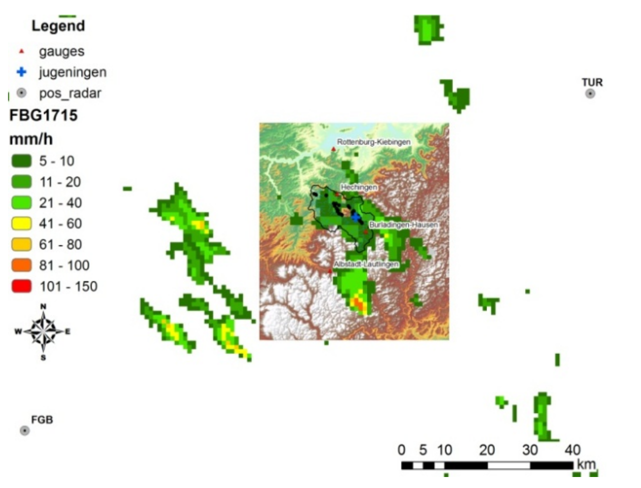
APPENDIX :

Original rainfall maps (unadjusted for attenuation) from the radar located at Türkheim (TUR) (60 km from the basin) and at Feldberg (FBG) (90 km from the basin) for two times during the flood (17:15 UTC and 17: 40 UTC). The Starzel basin closed at Rangendingen is also shown in the map.

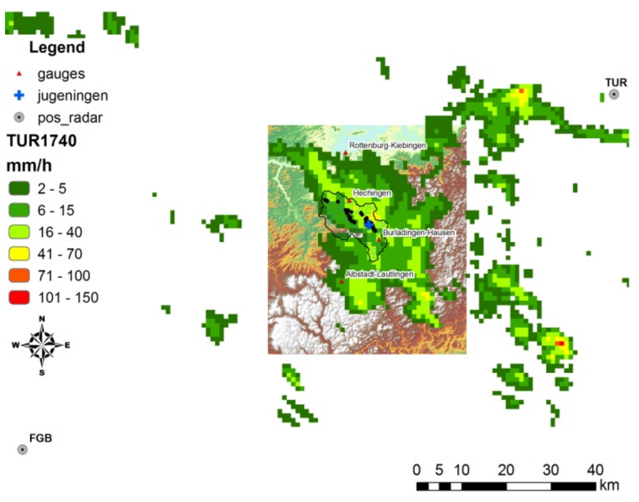
Radar TUR time: 17 :15 UTC



Radar FBG time: 17:15 UTC



Radar TUR time: 17:40 UTC



Radar FBG time: 17:40 UTC