Hydrol. Earth Syst. Sci. Discuss., 9, C5446–C5453, 2012
www.hydrol-earth-syst-sci-discuss.net/9/C5446/2012/

Hydrology and Earth System Sciences Discussions

Interactive comment on "Regionalised spatiotemporal rainfall and temperature models for flood studies in the Basque Country, Spain" *by* P. Cowpertwait et al.

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Received and published: 27 November 2012

We thank the referees for their helpful comments. Our replies to each referee and their comments (listed as RC #1 and RC #2 respectively) are given below.

Response to Referee #1

RC #1 (a): As stated one aspect of the project is to "provide a model for infilling the missing data". The model described in the paper is going to be used in various hydrological projects across the Basque Country, which include infilling missing data for daily water resources estimation. It is not feasible to cover the full details of this (and other projects) in this paper, which focuses instead on model development, calibration, and validation. To help with possible misunderstanding in this paragraph, we propose to include a reference to a similar infilling/disaggregation procedure and change the wording to: “About 73% of the data were missing over this period, with most missing in the earlier part 1914–1985. (The fitted model can be used to infill the missing data and disaggregate daily data to hourly values; e.g. see Cowpertwait, 2006.)”

RC #1 (b): As suggested, we will include an example extreme value plot.

RC #1 (c): In order to establish suitable soil moisture initial conditions for each of the 13 calibration events, so that the posterior fitting process could be reliable, an antecedent daily simulation using the historical records was conducted prior to the hourly simulation of the events. The soil moisture conditions from the daily simulations were used as initial states in the hourly simulations (in part, to reduce computational times). A transfer of soil moisture conditions between simulations is possible only if the model parameters that account for soil capacity at each level are maintained. In the case of the Urola basin, this was achieved – we imposed the same corrections factors for the daily and hourly simulations (with the exception of the rainfall interpolation factor), which gave good fits with 0.75, 0.69 and 0.80 R^2 values for B1Z1, B1Z2 and B2Z1 stations respectively during a daily simulation of 9 years. We propose to include an edited account of this on page 10385 (near line 26) when revising the manuscript.

RC #1 (d): The regionalization procedure used during calibration modified the original parameters maps of static storage capacity, soil hydraulic conductivity and subsoil hydraulic conductivity in the sub-catchments draining to each station. By doing so, a better spatial consistency was gained when using a unique set of correction factors for the entire basin, a technique not used in Velez et al.'s work. In addition, Velez el al. used a shorter period for calibration and validation and, consequently, correction factors in the most downstream station are not directly comparable. The following table shows the set of parameters related to B2Z1 station resulting from both pieces of work. Previous daily correction factors were not stated in Velez et al. article but were part of a previous work carried out as a consultancy contract for the Basque Water Agency. As can be seen, the differences are notable, and reflect the different aims in each study, the conceptual model being prone to temporal scale variation effects (especially in flow production factors), and the lack of a regionalization procedure in Velez et al. study. An edited version of these points will be incorporated into page 10386 of the manuscript.

Correction factor	Daily correction factors (previous work)	Hourly correction factors (current work)
R-1 Static storage	0.90	1
R-2 Evapotranspiration	0.92	0.92
R-3 Infiltration	0.052	0.17
R-4 Overland flow	0.333	0.06
R-5 Percolation	0.031	0.09
R-6 Interflow	333.2	650
R-7 Groundwater outflow	0	0
R-8 Base flow	43.8	20
R-9 Flow velocity	1.3	0.35
β - Rainfall interpolation	0.0025	0

RC #1 Technical Corrections:

These typographical errors will be corrected. The exception is the third one, where we mean “twelve estimates” (because each model parameter is estimated for each month, resulting in twelve estimates per parameter).

Response to Referee #2

RC #2 (2): As described in Section 2.1, the continuous superposed spatial-temporal Neyman-Scott model was published in WRR in 2010, whilst (as far as we know) this is the first application of the discrete spatial model (which, as mentioned in 2.1, is more straightforward for the practicing hydrologist to fit to data). Whilst the equations for the discrete superposed model are just the sum (or the product, in the case of the proportion dry) of previous expressions (as noted in the first sentence in Section 2.2), they provide a general extension that is of practical value leading to good fits to statistical properties (up to third order) for the three homogeneous regions (see Figures 4 and 5). The use of “two types only” is justified on p10371 (lines 11–15), and corresponds broadly to the two distinct precipitation types: convective and frontal systems (although the possibility of including additional types, e.g. due to orography, is not excluded; p10371). Furthermore, as far as we know, Stage 1 (p10375) of the fitting algorithm is new as are the resultant plots (Fig. 2). In addition, we could not find a full spatiotemporal temperature model like the one described in our paper (e.g. that used the first principal component to account for harmonic variation; Fig. 7; Tables 3-5) – in the literature, similar studies include the development of the weather generators, which we have noted on p10380 (lines 14–22), but these are still notably different from the study described in our paper. To address the referee’s point regarding the number of equations, we propose to put equations (1)-(6) in an Appendix in the revised manuscript.

RC #2 (3): This comment is essentially addressed in RC #1 (a) above. (In answer to the more specific question, we did not divide the daily data by 24; rather the approach will be similar to that used in Cowpertwait, 2006.)

RC #2 (4): The model uses max temperature as an explanatory variable (Table 5). So by “equal maximum temperatures” we just mean when the same value is used for this explanatory variable in the equation. The wording will be adjusted to clarify this point.

RC #2 (5): The sentences that the referee quotes could lead to some misunderstanding (and so we propose to edit these sentences in the revised paper; see below). Nevertheless, it is worth noting that the methodology presented in this paper is not intended to provide hydrological predictions as a flood early warning system might (although the same hydrological models described in the text are currently used in the Basque Country Flood Decision Support System to obtain flood forecasts), but aims to extrapolate the available meteorological and hydrological information to estimate high return period discharges, which are going to be applied in future work to develop flood risk hazard maps within the European Flood Directive framework. In this sense, the methodology can be regarded as predictive, because it makes use historical records to obtain possible extreme flood events via simulation, which it does whilst avoiding design storms with event hydrological modelling (thus avoiding the well-known uncertainties and problems therein). Hence, the methodolgy will be useful in these forthcoming flood hazard projects.

Hydrological calibration and temporal validation seems an appropriate way to test the capability of the spatiotemporal rainfall and temperature models, since this is how the models are going to be used in practice, so confidence that the models are "fit for purpose" can be gained. We propose to change the sentences that the referee comments on to:

- "In forthcoming projects, the fitted rainfall and temperature models will be used to generate long-term continuous flow simulations to evaluate design discharges in flood studies."
- "A unique set of correction factors is sought for the 13 calibration events. If this is achieved whilst maintaining high overall R^2 values, the fitted model should be of practical value in the forthcoming flood studies (subject to satisfactory validation)."

In addition, we propose to add the following sentence at the end of Section 5.3: "Calibrating the model to heavier events helped to ensure a satisfactory fit to annual maximum discharges, which are important in the intended application. Although this may result in some reduced goodness-of fit for smaller events, continuous daily simulations of 9 historical years gave R^2 values of 0.75, 0.69 and 0.80 for B1Z1, B1Z2 and B2Z1 stations respectively (similar to those obtained in Velez et al., 2009), indicating an overall satisfactory fit; in particular, with respect to soil moisture conditions which are important in the simulation of peak discharges."

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Interactive Comment

To address the last comment, we propose to change the text to “suitable for representing the hydrological response of the catchment during major flood events”.

RC #2 (6): Apart from the last event, the simulated peak discharges are not generally underestimated for station B2Z1. In fact, out of 13 calibration events, the model overestimates the peak discharge in 6 and underestimates it in 7, with an average difference for the whole set of -4%. It does not follow that if a model is biased to underestimate peak discharges during calibration, this will result in an overestimation during its later application. The differences seen in Figure 11, which are not statistically significant, may be caused by a sampling error in the observed record, which only comprised of 16 years (in comparison with the 500 years of simulated data). As suggested, a new Figure 10 will be provided with clearer fonts for the axes.

RC #2 (7): The regionalisation procedure mentioned in the text was the last step in the calibration process, and was intended to establish a single set of model correction factors for the whole basin (instead of three different ones for each of the three sub-catchments draining to each gauge station as previously obtained). As some of the correction factors affect the values of the three model parameters, a factor can be applied to the parameter maps in each sub-catchment so that the final value used in the equations is the same. However, there are two correction factors (R-3 “Infiltration” and R-6 “Interflow”) that affect soil hydraulic conductivity and two (R-5 “Percolation” and R-8 “Base flow”) that affect subsoil hydraulic conductivity. A unique value of R-4 “Overland flow” is used for the whole basin, whereas during the calibration of each single sub-catchment three different values were obtained as optimum ones. The regionalisation process is iterative, aiming to reach balanced values for an overall good fit, and differs from the one applied in Velez et al. (2009), where calibration was only made in the most downwards station (in this case B2Z1), thus leading to a worst performances in the upwards stations. The following sentence will be added to the end of the paragraph and some minor edits (as in RC #1 (d)) made: “This process implies that parameter maps were affected by factors in each sub-catchment; an iterative process was used to reach balanced values of the model correction factors to provide an overall good fit".

RC #2 (8): The following sentence will be added at the end of the conclusions: "These will include obtaining high return period discharges for river networks in the Basque Country, which will be used to predict flood risks within the European Flood Directive framework".

RC #2 (specific comments):

- As suggested, we will rephrase the text.
- A new Figure 9 will be provided to include the name of the Urola river and its tributary the Ibai-Eder river
- This will be changed to: "The TETIS model was selected to simulate the hydrological processes".
- By substrate hydraulic conductivity we mean the hydraulic conductivity of the aquifer layer contributing to the base flow. We will change it to subsoil.
- We will change this to: "These correction factors are calibrated using a set of recorded events. The Nash-Sutcliffe efficiency coefficient (or R2) is used to assess the goodness-of-fit."
- The Beven (2000) reference is misplaced. Instead we will use Pappenberger and Beven (2004: 93): Pappenberger, F. and Beven. K.H. (2004) Functional classification and evaluation of hydrographs based on Multicomponent Mapping (Mx). International Journal of River Basin Management, 2 (2): 89–100
- The 3 maps of parameter are the ones mentioned in page 10385: the static storage capacity, the soil hydraulic conductivity and the subsoil hydraulic conductivity.
- Abs. peak error stands for Abs(SIM-OBS)/OBS.

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- These are in the caption for Table 8. We will look at specifying them in the text as well.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 9, 10365, 2012.