RECONSTRUCTION OF SUSPENDED SEDIMENT DATA DURING FLOODING EPISODES WITH STOCHASTIC SIMULATION

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Introduction

Very extreme rainfall episodes is increasingly becoming a major concern in terms of risk erosion and solute denudation, especially in Mediterranean environments where after a dry summer, autumn storms cause significant flashfloods (Outeiro *et al*., 2007). The occurrence of high intense storm rainfall in the western Mediterranean results in severe and often catastrophic floods. High resolution temporal data is required in order to assess the effects of these rainfall episodes and its hydro-ecological response. But, unfortunately during these episodes instrument measurements are sometimes experiencing technical problems or even they are not able to log data. Suspended sediment concentrations extrapolation has been a traditional topic to discuss given that rating curves relating concentration and discharge always tend to underestimate or overestimate concentrations (Walling, 1977; Walling, Webb, 1988). Several procedures and methods have been developed and applied to correct such bias (Ferguson, 1986; Asselman, 2000; Holtschlag, 2001). Consequently researchers are forced to look for cost-effective solutions to these technical problems. Our goal is the reconstruction of hydro-events of which there is no available data with modelling and then simulation of suspended sediment with alternative methods to those already used in the hydrological predictions literature. Then, we compare the simulation results with those yielded by the regression techniques.

Study area and materials

Vernegà stream is an order 1 of the Ter river drainage watershed according to Strahler classification. This headwater stream is an intermittent or seasonal type due to the limited and highly variable rainfall and due to the geologic nature (granites). Climate is Mediterranean sub-humid with mean annual rainfall registered in the study area around 600mm, and a major part of it is collected during fall and spring seasons. The hydrological regime is defined by two Mediterranean features: low discharges with a drought period between May and October (Sala *et al*., 2001). The instrumentation materials are the following: water stage recorder OTT type, automatic sampler ISCO 3700. This instrument was programmed to take samples every 1 or 2 hours during a flood event from a starting stage of 10 cm.

As already stated, the hydrological regime of this stream forces us to study the suspended sediment simulation only during episodes. The episode chose to complete the simulations happened in late winter 2006.

Methods

The software used to yield the simulations is the v7.0 of GS+ (Gamma software Inc.) which is based on GSLIB principles (Deutsch, Journel, 1997). The concept of the simulation used in our study lies on the sequential conditional simulation (SCS) techniques used by GSLIB. As stated in the book of Deutsch and Journel (1997) the sequential simulation principle allows drawing the value of a variable *Z(u)* from its conditional distribution given the value of the most related covariate at the same location *u*. In this process some elements of modeling are used for the variable simulated (suspended sediment) as for the most related covariate (discharge). These modelisation elements include deterministic algorithms; cdf, semivariograms and covariance function. Also these modellings include on its simulation step stochastic parameters and algorithms, as randomization seed, multigrid refinement and number of simulation for each node, radio of search and number of neighbors.

Results and Discussion

Sequential Conditional Simulation modelling

SSC measured data was modelised with semivariogram algorithms. The semivariogram fitted to the measured data is presented in figure 1 including in the same figure the parameter values.

The results of the fitted model in the semivariogram are the following: Residual Sum of Squares: 0.0000368, R^2: 0.448, proportion $C/(C_0+C)$: 0.998. It is important to note the low number obtained in the RSS parameter which denotes how well the model fits the semivariogram. The lower the RSS, the better the model fits. When simulating with this type of simulation model, some parameters are needed to feed the model for each run. These parameters are: search neighborhood; radius: 6 and number of neighbors: 2. Number of simulations: 1000 for each node (in our case, for each hour). In our simulation runs, the randomization seed was not used due to the unrealistic output results produced when the randomization seed was used. Multigrid refinements were not used either in our simulations. In this simulation run, a standard deviation for each of the node is calculated by the software to give an idea of how much inconsistency your model gets. Our runs obtained a standard deviation of 0.33 g·dm^{-3}.

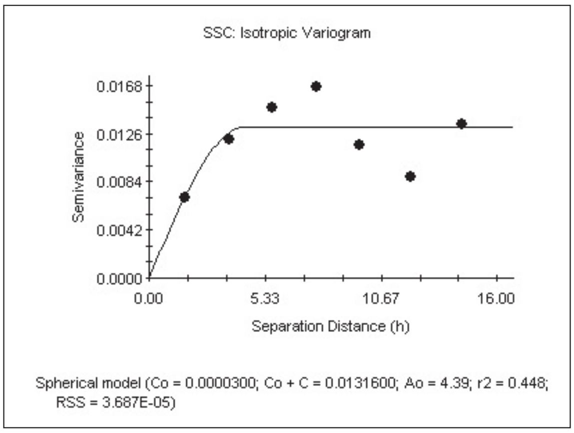

Figure 1. Semivariogram and covariance graphics of the model fitted to the measure data of SSC (g·dm^{-3})

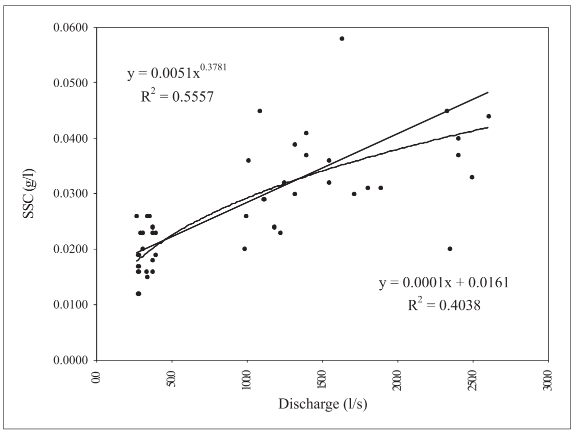

Figure 2. Regression model

Regression model

In order to compare the simulation results of SSC with other models, we consider two type of fitted models of the regression model, the linear and exponential. Quite satisfactory R^2, 0.44, was obtained in the linear regression between discharge (dm^3·s^{-1}) and SSC (g·dm^{-3}). Equally for the R^2 of the exponential model which was 0.55. As stated by Asselman (2000) and Walling (1974, 1978), the most commonly used sediment rating curve is a power function, being our results of the regression model consistent with what these two autors stated. In the figure 3, it is noticeable how the exponential model tend to overestimate the SSC values and how the linear model tend to underestimate the SSC values. This was also found by Walling (1977) and Walling and Webb (1988), who stated that rating curves relating concentration and discharge tend to underestimate or overestimate sediment concentrations.

Comparison of the results with simulation and regression models

Conditional sequential simulation is based on a form of stochastic simulation in which measured data values are honored at their locations. Also, SSC simulation uses an ancillary variable (discharge) for every grid node of the SSC hourly non measured data. This can be observed in figure 3 where the results of the different models are displayed. So, it is noticeable how the SSC-simulation follows exactly the same path as the SSC-measured data for the period of hours that we have this data available (the black line). Consequently, the results of the cross validation are consistent with this statement. The R^2 of the cross validation between SSC-measured against SSC-regression linear and exponential are 0.11 and 0.12 respectively, whereas the R^2 of the cross validation between SSC-measured against SSC-simulation is 1. Thus the simulation model reproduces faithfully into the model the available measured data used to feed the model. Table 1 showed descriptive statistics of what was achieved for the different models thus make easier to compare the yieldings of each model with other observed-measured values of the same watershed in other hydrological events or even with other basins of the same nature. So, in Arbúcies basin which is also a sand river basin next to this study area, the SSC measured had its maximum peak in 2.67 $g \cdot dm^{-3}$ (Batalla, 1992). Moreover in this study area the SSC measured during October 2006 during a maximum peak discharge of 1000 $dm^3 \cdot s^{-1}$ was 1.06 $g \cdot dm^{-3}$. Both measured values are more similar to those produced by the simulation model than the ones of the regression. During the high peak the slope described by the SSC-simulation model seems to adapt better than in regression model to the sand river bed nature of this basin, or at least more realistically than the slopes described by the regression models. Thus the upward settling increases in the same fashion as discharge does. Therefore, we can observe that the simulation models reproduce faithfully this dynamic.

Table 1. Statistics of the simulation and regression results

	Mean	Max	Min	SD	CV
SSC-simulation	0.59	1.57	0.03	0.37	0.63
SSC-regression linear	0.07	0.14	0.04	0.02	0.33
SSC-regression exponential	3.75	8.96	1.82	1.62	0.43

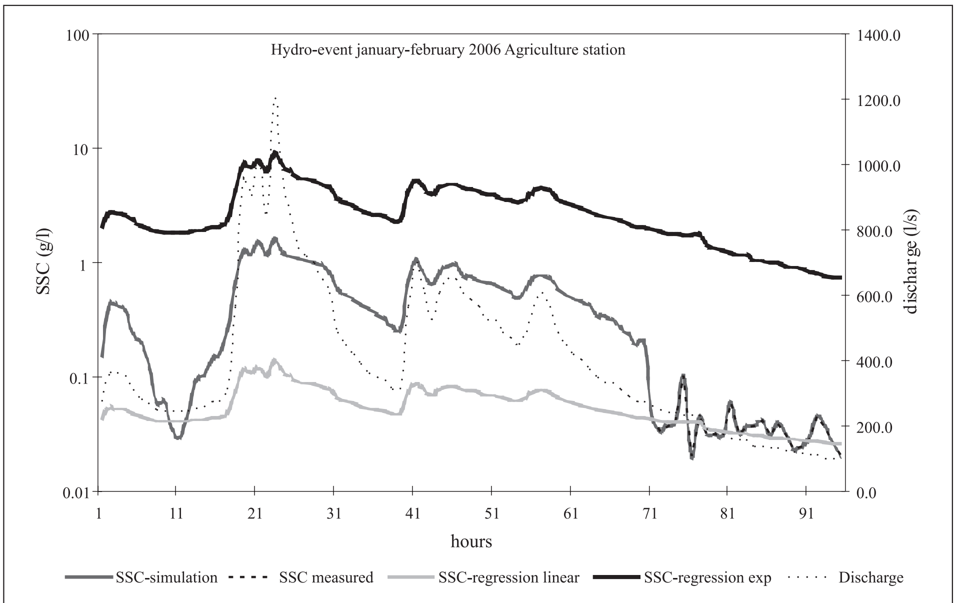

Figure 3. Results of SSC produced with regression and simulation techniques

Summary

The simulation model gives back a more consistent and realistic result than the regression model when calculating the SSC for maximum peaks discharge values. Also during recession the simulation model generates a consistent result with the sand river bed nature of this basin. Mean values of the series yielded by the regression model seems to be more unrealistic values than the ones yielded by the simulation model. More data of storm-rainfall episodes are needed to validate both types of models, but especially the regression model. Despite the stochastic nature of hydrological parameters can give new insights of these techniques, the use of stochastic simulation in hydrological science is far to be developed. Being this study a new experimental approach to join the stochastic techniques together with hydrological variables.

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