Development of a graphic interface and an automatic calibration module for MGB-SED model

Rodrigo Sanchotene Quintela [1]*; Victoria Ache Rocha Lopes*[2]*; Hugo de Oliveira Fagundes* [3] *& Fernando Mainardi Fan* [4]

ABSTRACT - Coupled hydrological and sediment models are useful tools to study sediment dynamics and its alteration due to human activities. Many models have been developed in the past few years. One of this new sediment model is the MGB-SED, which is coupled with the hydrological model MGB to study large-scale basins. Since it is a recent model, MGB-SED requires some enhancement, which lead to the two goals of the present study. First, it was developed a user-friendly interface in order to compare MGB-SED calculated values of sediment concentration and observed data for sediment concentration. Second, some of parameter for calibration are adjustment coefficients and do not have a physical meaning, which makes their manual calibration more challenging. So, the evolutionary algorithm MOCOM-UA was used to calibrate automatically two parameters of MGB-SED using three objective functions. The observed data of sediment concentration used in calibration was obtained from one station located in Camaquã River in Rio Grande do Sul, Brazil. Results showed that the algorithm allowed for the estimation of the Pareto front aiding in the achievement of better results of objective functions. At the same time, the new graphic interface reached its aim, adding a new alternative of data analysis for the user. The present study, therefore, can consist in an improvement of the sediment production and transport model MGB-SED.

Keywords – MGB-SED, Sediments, Hydrosedimentological modeling

1. INTRODUCTION

Understanding sediments dynamic is important to analyze environmental and social effects caused by human activities and climate changes. Hydrological models coupled with sediments models are useful tools to investigate sediments production and transportation. Associating them is indispensable, once their natural cycle are tightly connected. On that account, many hydrological models, such as SWAT (Arnold *et al.* (1998)) and SWIM (Krysanova *et al.* (1996)), have modules to simulate sedimentation processes.

MGB hydrological model (Collischonn *et al*. (2007)) coupled with MGB-SED production and transportation sediments model (Buarque *et al.* (2013) and Buarque (2015)), is a good alternative to study hydrosedimentology in large-scale basins. New calibration parameters are introduced

---

[1]) Universidade Federal do Rio Grande do Sul, Av. Bento Gonçalves, 9500, rodrigosquintela@gmail.com, (51) 991315442
[2]) Universidade Federal do Rio Grande do Sul, Av. Bento Gonçalves, 9500, varlopes@gmail.com, (51) 33086414
[3]) Universidade Federal do Rio Grande do Sul, Av. Bento Gonçalves, 9500, h.o.fagundes@hotmail.com, (51) 3086670
[4]) Universidade Federal do Rio Grande do Sul, Av. Bento Gonçalves, 9500, fernando.fan@ufrgs.br, (51) 33086414

when both models are combined. However, some of these parameters do not have a physical meaning, which makes their manual calibration more defiant.

Therefore, the present study sought to make two enhancements required by MGB-SED model. Firstly, a user-friendly interface was developed to compare MGB-SED calculated and observed sedimentograms in order to help data analysis. Secondly, a multi-objective evolutionary algorithm was utilized to automatically calibrate model parameters, simplifying the application.

2. MGB-SED - MODEL

MGB-SED has two main modules: (1) sediment production and contribution in watercourses and (2) sediment transportation into it. Both components are independent, so, results coming from MGB are used as input in modules 1 and 2.

The model adopts Modified Universal Soil Loss Equation (MUSLE), Willians (1975), to estimate sediment production for each Hydrological Response Unit (HRU) in a mini-basin (calculation unit). The MUSLE is shown on Equation 1:

$$SED = a.(Qsup.qp.A)^{b}.K.C.P.LS \qquad (1)$$

Where SED (t) is the sediment yield to the stream network, $Qsup$ (m^3) is the runoff volume from a given rainfall event, qp(m^3/s) is the peak flow rate, A(ha) is the HRU area, K ($0.013.t.m^2.h.m^{-3}.t^{-1}.cm^{-1}$) represents the soil erodibility factor, C(-) is the cover management factor, P(-) is the soil erosion control practice factor and LS(-) is the slope length and gradient factor.

Buarque *et al.* (2013) considered the location coefficients a and b as fixed parameters and equal to 11.8 and 0.56, respectively. Though these parameters are adjustment coefficients and do not have physical meaning, they can be calibrated to obtain better results. Therefore, a and b were the parameters automatically calibrated in the present study.

Sediments calculated using Equation 1 are divided in three fractions that are carried through the mini-basin until the stream network. More details about MGB-SED model can be found in Buarque *et al.* (2013) e Buarque (2015).

3. GRAPHIC INTERFACE

In order to compare sedimentograms calculated by MGB-SED model with sedimentograms generated from observed data, it was created a visual interface to help the user. To achieve this, the programming language chosen was Visual Basic and Microsoft Visual Studio was adopt as an Integrated Development Environmental. Using inputs coming from MGB-SED, such as silt, sand and clay concentrations, this program shows sedimentograms for any minibasin requested by the user. It is possible to exhibit both graphs for isolated sediments fractions and two or three added, clay plus sand concentrations for instance. Besides, the program also generates solid discharge graphics. Figures 1 and 2 show the interface and a sedimentogram calculated by the program, respectively.

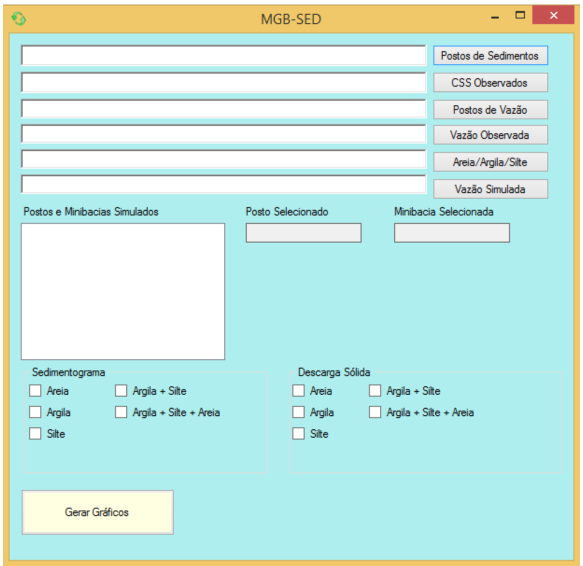

Figure 1 – Sedimentograms comparator.

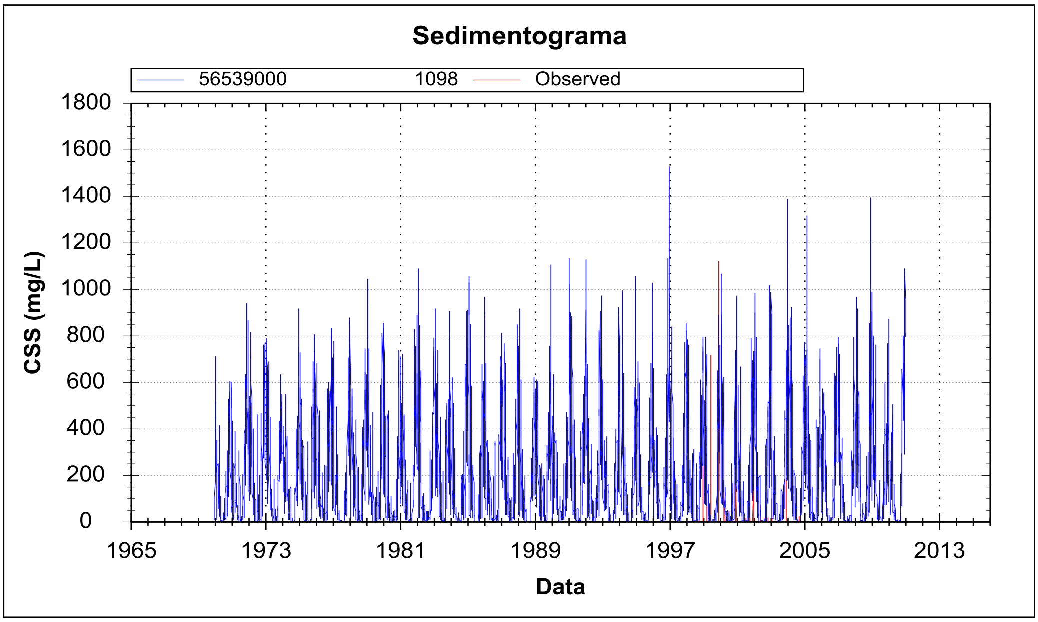

Figure 2 – Sedimentograms created by the program.

4. AUTOMATIC CALIBRATION MODULE

4.1. Multi-Objective Algorithm

Presented by Yapo *et al.* (1998), MOCOM-UA (*Multiple-Objetive Complex Evolution – University of Arizona)* was the algorithm selected for this study. MOCOM-UA uses techniques of random search, genetic algorithms and Nelder and Mead method. Collischonn and Tucci (2003) used this algorithm to calibrate MGB hydrological model and MOLCOM-UA was chose for the present paper due to this. It is important to emphasize that the number of "p" points in an initial population affects MOCOM-UA and, despite requiring more time for processing, greater population achieve better results in terms of Pareto efficiency.

More details about MOCOM-UA algorithm can be found in Yapo *et al.* (1998) e Collischonn e Tucci (2003).

4.2. Model settings and studied areas

The Camaquã river watershed was selected as the area of study. This basin has around 17000km² and it is located in Brazilian southern, Figure 3. MGB model has been previously gauged with observed flow data from the gauging station number 89705000 and to a period between 01/01/1990 and 31/12/2010. All observed streamflow information used as input for MGB is available on Brazilian National Water Agency (*ANA - Agência Nacional de Águas*) website.

Observed sediments concentration from the same date and station mentioned above were selected to calibrate the parameters "a" and "b" from MUSLE equation. For the studied period, there is a substantial absence of data, since just 36 measures was taken in 20 years. This fact does not preclude the process, but it decreases the accuracy of the calibration, no matter it is automatically or manual done.

A population of 20 individuals was taken into account and the process was run twice to observe if the Pareto zones found were similar or if a bigger population is required in order to achieve better results. Three multi-objective functions were considered: Nash-Sutcliffe coefficient (NS), Nash-Sutcliffe concentration logarithm coefficient (NSL) and the relative error between the averages of simulated and observed concentrations (EMED).

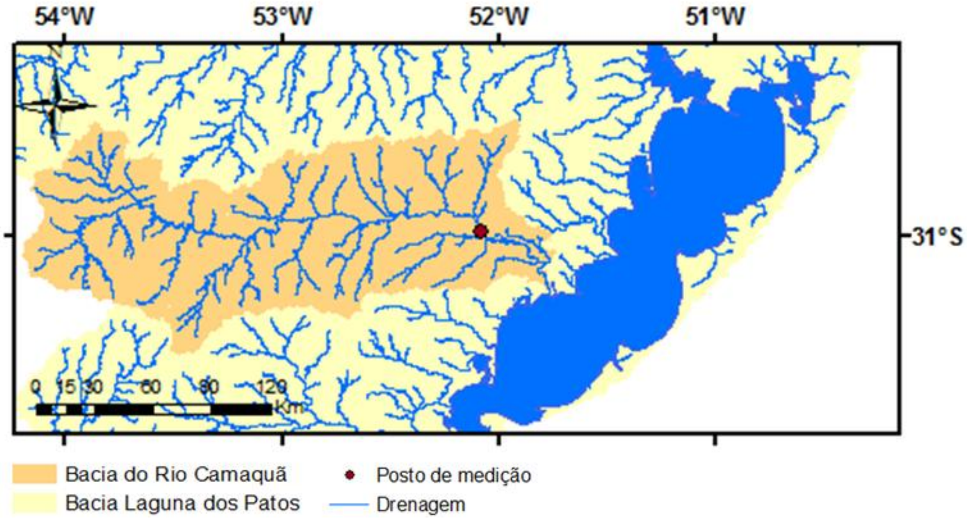

Figure 3 – Area of study and measure station.

All climate date required were collected from a MGB database produced by Fan and Collischonn (2014). The digital elevation model of SRTM, Farr *et al*. (2007), was utilized to discretize the watershed in 250 minibasins and to settle the topographic characteristics as well. The HRU needed and MUSLE parameters were defined based on a South America HRU map, Fan *et al.* (2015).

4.3. Automatic calibration testing

During the first automatic calibration process, 53 simulations were run, which 20 corresponded to an initial population generation and 33 to new points obtained by the evolution process. This operation was performed 28 times until the algorithm converged to an approximation of a Pareto curve, Figure 4. The blue points denote all points generate in calibration process which are dominated by the red ones. The black point represents the solution when MUSLE parameters “a” and “b” are settle as 11.8 and 0.56, respectively. It can be noted that this solution is far from the optimum curve calculated, being less precise than an automatic calibration.

Figure 5 compares the Pareto sets achieved in first and second calibrations. Both of them had 20 individuals as initial population, but the second one needed just 39 cycles to generate de Pareto zone approximation. Blue points represent the second simulation and red ones express the first process.

Analyzing Figure 5, it calls attention that, despite having just 20 individuals, the simulations engender similar Pareto sets. Nonetheless, it can be notice that the first simulation generated a point dominated by points from the second solution. Therefore, the number of individuals should be risen to avoid this dominance.

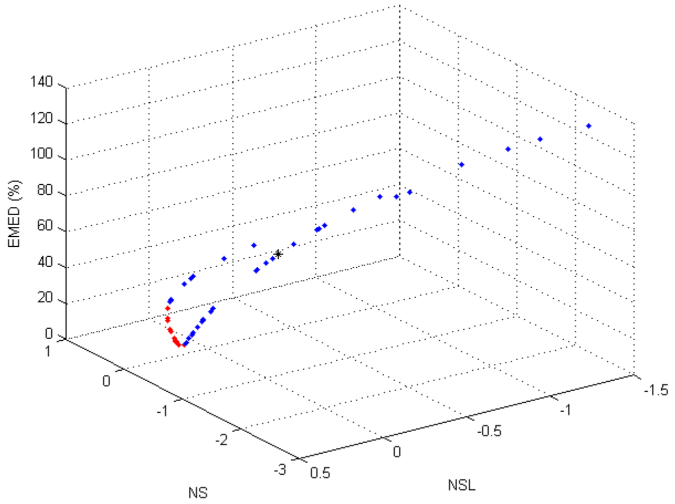

Figure 4 – Multi-objective functions results for each point simulated in automatic calibration process.

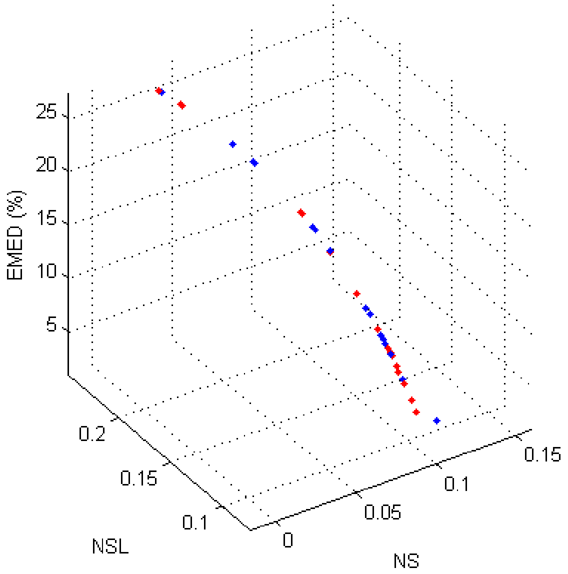

Figure 5 – Multi-objective functions results for the Pareto's zones calculated in calibration 1 (blue) and 2 (red).

Table 1 shows four points selected from calculated Pareto sets as well as the point previously considered, representing the values of associated parameters and the objective functions. The sampled points correspond to three points with best values for each metrics and one point with intermediary values of all metrics.

Still on Table 1, it is realizable a considerable enhancement in the performance metrics when observed and calculated points are compared in Pareto zone. This behavior can be related to absence of observed data. The relative error between the means had a substantial improvement, achieving satisfactory results in some points in Pareto zone (near 1%).

Table 1 – Solutions in Pareto's set and previous solution calculated with fixed parameter values.

Pontos	**Parâmetros**		**Funções Objetivo**		
	a	**b**	**NS**	**NSL**	**EMED (%)**
Ponto anterior	11,8	0,56	-0,253	-0,332	48,6
Pareto maior NS	7,478	0,417	0,119	0,125	1,7
Pareto maior NSL	5,675	0,505	0,027	0,226	27,4
Pareto menor EMED	8,64	0,872	0,118	0,120	1,0
Pareto intermediário	8,088	1,027	0,106	0,183	11,6

Figure 6 indicates simulated concentrations related to solutions of Pareto zone mentioned in Table 1, to the preview solution and to observed data. It is possible to detect a reduction in simulated concentration values and in its range as well. On that account, a better performance in observed data representation can be notice.

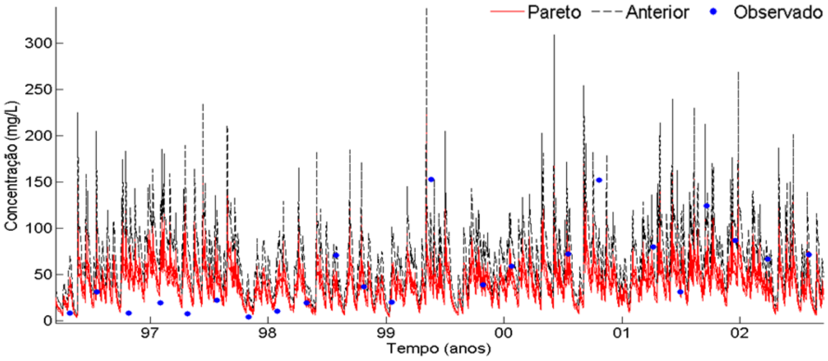

Figure 6 – Simulated and observed concentration versus time for measure station 89705000, calculated in points in Pareto's zone and in previous points with fixed coefficients

5. CONCLUSION

The graphic interface developed reached all proposed goals and, now, MGB-SED can offer to users an option to analyze theirs results in a visually way.

Results obtained with automatic calibration indicated that this method helped to achieve better performance metrics results and it can be useful to estimate MUSLE coefficients in another studies. In addition, the study prove that to define values of 11.8 and 0.56 for parameters "a" and "b" did not provide the best results, despite being used for a long a time. As demonstrate in this study, the MOLCOM-UA algorithm is a useful tool to optimize these values.

BIBLIOGRAPHY

Arnold, J. G., Srinivasan, R., Muttiah, R. S., & Willians, R. S. (1998). Large area hydrologic modeling and assessment part I: model development. *J. Am. Water Resour. Assoc.* , V. 34, p. 73–89.

Buarque, D. (2015). *Simulação da geração e do transporte de sedimentos em grandes bacias : estudo de caso do Rio Madeira.* Istitudo de Pesquisas Hidráulicas, UFRGS, Porto Alegre, RS, Brasil: Tese de doutorado.

Buarque, D., Collischonn, W., Paiva, R. C., Tucci, C. E., & Guyot, J. L. (2013). Modelagem da produção e do transporte de sedimentos da bacia do Rio Madeira. *Anais do XX Simpósio Brasileiro de Resursos Hídricos.* Novembro de 2013. Bento Gonçalves.

Collischonn, W., & Tucci, C. E. (2003). Ajuste Multiobjetivo dos Parâmetros de um Modelo Hidrológico. *Revista Brasileira de Recursos Hídricos*, V. 8, n.3, p. 27-39.

Collischonn, W., Allasia, D. G., Silva, B. C., & Tucci, C. E. (2007). The MGB model for large-scale rainfall-runoff modelling. *Hydrological Sciences Journal*, V. 52, p. 878-895.

Fan, F. M., & Collischonn, W. (2014). Integração do Modelo MGB com Sistema de Informação Geográfica. *RBRH - Revista Brasileria de Recursos Hídricos. Volume 19,* 243-254.

Fan, F. M., Buarque, D. C., Pontes, P. R., & Collischonn, W. (2015). Um mapa de Unidades de Resposta Hidrológica para a América do Sul. *XXI Simpósio Brasileiro de Recursos Hídricos.* Brasília, DF.

Farr, T. G., Rosen, P. A., Caro, E., Crippen, R., Duren, R., Hensley, S., et al. (2007). The Shuttle Radar Topography Mission. *Reviews of Geophysics*, V. 45(2).

Krysanova, V., Miller-Mohlfeil, D. I., & Becker, A. (1996). Mesoscale integrated modelling of hydrology and water quality with GIS Interface. *In Anais do Troc. Third Int. Conf. on Integrating GIS and Env. Modeling.* Santa Barbara: California National Center for Geographical Information and analysis.

Willians, J. R. (1975). *Sediment-yield prediction with universal equation using runoff energy factor.* US Department of Agriculture: Washington, DC; pp. 244–252: In: Present and Prospective Technology for Predicting Sediment Yield and Sources. Publication ARS-S-40.

Yapo, P. O., Gupta, H. V., & Sorooshian, S. (1998). Multiobjective global optimization for hydrologic models. *Journal of Hydrology*, V. 204, p. 83-97.