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Average daily flow estimate using the model mobile media in the watershed of Uruçuí Preto river - PI, Brazil

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Abstract

The estimate of runoff in watersheds is of great importance for planning, management and conservation of natural resources. However, this estimate is complex from the point of view of the spatial variability of the variables under study, without considering the scarcity of streamflows in watersheds. Knowledge of a rainfall-runoff model that is suitable for a watershed is of fundamental importance to the success of this estimate as well as the development of projects within the basin. Thus, the aim of this study was to use the IPH II model to estimate the daily mean streamflows in Uruçuí Preto river basin (BHRUP). The correlation coefficient between observed and calculated streamflows was 0.95 and the mean square error was equal to 8.2%. The mean square error was influenced by peak of flows was not made during the calibration process. Through simulation it was found that the BHRUP was occupied with 100% pasture, there would be increased soil moisture and as a result there would be major flood peaks with more severe and frequent flooding.

Keyword: Simulation, water conservation and IPH II hydrologic model.

1. Introduction

The floods in Brazil and worldwide has intensified due to direct relation to the intensity and magnitude of rainfall according to (Grimm, 2011; Min et al., 2011). Therefore, it is necessary to have knowledge of the way rain is distributed spatially and temporally in studies related to the management, soil and water conservation, and construction of waterworks, to define the design flow described in (Roberts, 2008; Cecílio, 2009; Santos et al., 2010; Aragão, 2013). Thus, intensive studies are conducted to maximum precipitations having a rain exploration behavior throughout the years in order to avoid future disasters.

The planning and management of water resources of a river basin requires a thorough understanding of them. This implies disposal over time as well as the geographic area of the watershed, information on the quantities of stored water to flow in the drainage network, the uses of water resources and water quality.

The importance of management and planning of water resources increases in the proportion in which these features are presented in a sparse manner, especially in semiarid regions of the world where there are low rainfall rate, high evaporation and uneven spatial-temporal distribution of rainfall. In these regions water is a fundamental element in the socio-economic framework of the region, creating the need for rationalization of their use. Therefore, the planning of water resources is of critical dimension; through it are established guidelines to follow to provide better utilization, control and conservation of these resources as described by Galvíncio (2002).

Hydrological measurements are an important background information, but they are not continuous in space and time. In northeastern Brazil (NEB), perhaps more than elsewhere, there are few historical series of information available when the volumes stored in reservoirs or to flow into waterways and practically non-existent those related to water quality. Since the information about precipitation are denser and generally lies relatively long time series.

In climate region of contrasting nearby (for a rainy side of the other semi-arid), as the NEB and in particular the state of Piauí, monitoring of rainfall, especially during the rainy season is very important for making decisions that bring benefit for population. Good monitoring of rainfall is an indispensable tool in the mitigation of droughts, floods, flood, floods, flooding according to (Paula et al., 2010).

The assessment of climate change impacts on water resources of a watershed or region can be performed from the simulations own climate models according Milly et al. (2005) and UK Met Office (2005) or using precipitation and the air temperature calculated by such models as input in hydrological models according to the authors Vicuna et al. (2007).

From earliest times man seeks to know, empirically, and most recently in a scientific way, how to develop the complex interactions of the environment. In water resources, looking synthesize this knowledge through models that can qualify to quantify and manage the available water in the hydrological cycle. On projects in the area of water resources, it is necessary to know the number of flow records. This series must be representative of the events in the watershed, and therefore composed of long-period data. From this data, the researcher seeks to know the full project, which is the biggest flood for which a given water works will be projected. In contrast to this need, often these series are short and often do not exist. This scarcity or lack is due to the high cost of obtaining and/or the management model of water resources in Brazil. The way out of this impasse is the modeling of flow series.

Beven and Moore (1994) worked with rainfall-runoff models that take into account the relevant parameters, geology, soil type and the type of land use. According Bruijnzeel (1997) and O'loughlin et al. (1990) hydrological models can be useful in watershed management, for both their planning and to assess the impact of changes in land use. For this, the model needs to describe the dominant processes properly and apply a basin where the soil and vegetation vary spatially, so that forecasts can assist in making decisions on what land use is the most interesting for a given situation. Hydrologists have developed mathematical models capable of transforming rain in flow through a set of equations that seek to represent the various stages of the water cycle, according to (Tucci, 1998).

Maksinovic (2001) warns that the basins should be used as a planning unit and management not only water, but also from other resource and economic and human activity, where any intervention should be studied and assessed its consequences and benefits for the basin. In the semiarid region, humid, subhumid, cerrado, savanna and the NEB transition zone, where the rivers are intermittent, the main way to store water and make it available to the various uses to which it is done is by building dams that when a course of spreadable water, cause storage.

With urbanization, the cover of the basin is largely sealed with buildings and floors and are introduced conduits for storm water runoff, generating the following changes according (Tucci, 2007):

Oliveira et al. (2010), recalls that when he leaves the rains, the rivers continue to "run" for some time, fed by waters that drain the saturated ground at higher levels than the main channel or "living chain" of River.

To completely stop the river's base flow water continues to flow into the "package" of dendritic sediments (gravel, sand, silt and clay) which together constitute the alluvial deposit described by (Oliveira, 2001). When the river ceases to "run" on the surface, this flood will gradually lose their accumulated water reserves and may have to dry completely in the dry season.

The work of Benoit et al. (2000) contributes towards the coupling between atmospheric and hydrological models at regional scale, performing case studies for several southeastern sub-basins of the river basin Ontario, Canada. To achieve this purpose we used the distributed hydrologic model Watflood, developed by the University of Waterloo, atmospheric model coupled to a non-hydrostatic mesoscale, integrating them into horizontal resolutions of 35, 10 and 3 km. The hydrological model was fed derived rainfall radar King City, and with observations of rainfall and gauged stations available for the case, this has allowed multiple comparisons and validations. Thus, the experiment explained some uncertainties associated with each of the tools, hydrological model and atmospheric model and demonstrates the complementary nature of these models, when used together. The predicted rainfall patterns were compared with measurements of rainfall stations and radar data. It has been shown that the hydrological model is sufficiently sensitive and suitable for diagnosing errors in both the model data as the radar, being a new and interesting tool to validate and interpret results produced by atmospheric models. The dependence between basins and sub-basins can be very useful for understanding the potential problems arising from the spatial changes of events in the atmosphere modeled.

In the climate issue, for example, Silva, (2004) and JJ (2004) presented a researched that interrelate weather phenomena observed to flow in watersheds. A classic example of this connection between climate and hydrological phenomena is the relationship between El Niño and La Niña with the positive and negative anomalies flows in some members basins of the (set SIN), especially those located in the South and Northeast Brazil, as already mentioned.

The statistical approach can highlight, according Tucci (2002), which defines the minimum flow or drought, as the flows that at a certain time series have the lowest values of the series or that do not meet the needs of demands.

Flow forecast is a real challenge used for the management of water resources in a pan according to the authors (Moraes, 1995), (Moraes, 1996). The flood forecasting, soil moisture for agriculture, navigation levels of a route, the water availability for water supply, irrigation and energy production are known uses for a prediction of flow in a river basin, described in (Tucci, 2002).

Smakhtin (2001) states that natural factors that influence the behavior of minimum flows, either for gain or loss, include: the distribution and soil infiltration properties, the hydraulic characteristics, extent of aquifers, the rate and frequency of recharging the aquifer, the evapotranspiration of the basin, the distribution of vegetation, topography and climate.

Souza et al. (2010) applied the IPHS I model in the watershed of the river Araguari to simulate the change in flow with precipitation and verify possible environmental impact on output flow due to construction of dams along the river. The authors found that the hydrological model showed significant results in the representation of the hydrograph at specific points in the basin, but with small discrepancies between observed and simulated. These discrepancies were verified due to lack of data. The authors suggest methods to obtain this additional information, based on (Fill, 1987; Rao and Srinivas, 2006; Eslamian and Biabanak, 2008; Samuel et al., 2011), and also in Malekinezhad et al. (2011). A model, according to (Tucci, 2005), is a simplified representation of an object or system, a form of easy access and use in order to understand it and seek their responses to different inputs. Due to the complexity of the physical nature, the model takes into account some simplifications of the existing phenomena in the process. Among the rain-flow designs, there are specific ones which can be used for such purposes, depending upon the parameters and characteristics of the basin (Herman et al., 1998). In the literature there are different rainfall-runoff models: HEC-1, SSARR, IPH2, Stanford IV and Hymo among others said Viegas et al. (2004).

Thus, it is noted that modeling itself encompasses a number of variables. Here though not explicit modeling variables, it is understood that they are represented in the estimates. In this understanding, the goal of this work is to use the IPH II model to estimate the daily media flows in the river basin Uruçuí Preto (BHRUP).

2. Materials and methods

2.1 Area description and data

The river basin Uruçuí Preto (BHRUP) is stuck in the sedimentary basin of Parnaiba River, its main tributaries are: Ribeirão dos Paulos, Castros, Spoons, Morro waters, stream of stowage and stream current, both perennial. This system is one of the main tributaries on the right bank of the Parnaíba river. The area BHRUP is about 15,777 km^2, representing 5% of Piauí territory and covers part of the Southwest region, protruding from south to north lance-shaped, according to CONDEPI (2002). The BHRUP is between the geographical coordinates of 07° 18'16 " to 09° 33'06 "S 44 ° 15'30 and " 45° 31'11 " W Greenwich.

Fluviometric stations located in the municipality of Jerumenha and Cristino Castro recorded average flow rates from 6.9 to 6.1 m^3s^{-1} in the driest quarter, respectively. And average flow rates of 90 m^3s^{-1} - 54 m^3s^{-1} in the wettest quarter. The average rainfall is 913.9 mm/year across the pond, the average evaporation is 1470.7 mm / year. The soil is represented by Neossolo types, Neossolo Quatzarêncio, Hidromófico and Oxisoil, according to (EMBRAPA, 1986). The vegetation is typical savannah, consisting of shrubs and arboreal discontinuous strata characterized by crooked trunks, thick bark, leaves and cariáceas asymmetrical canopy. The most common species: Barbatimão, Pau Land Large Leaf and Simbaíba. The ground is covered by grassy stratum of wild grass. The cerrado develops more closed form by larger species, including the Pau D'Arco and Gonçalo Alves.

According to Medeiros (2013), and based on Köppen classification (1928), distinguished two climatic types in BHRUP, the Aw, hot and humid tropical and BSh, semiarid region. Both with summer rains and dry winter. For this analysis we used data of average monthly and annual rainfall, acquired from the Northeast Development Superintendence (SUDENE, 1990), the Enterprise Technical Assistance and Rural of Piauí State Extension (EMATERPI) and the National Institute of Meteorology (INMET) for the period from 1960 to 1990. For the modeling were used 49 daily rainfall series, under the BHRUP (Figure 1), 30 years, 1960-1990, with data collection interval that meets the requirements of rain- model flow applied here. The flow data were kindly provided by the São Francisco Hydroelectric Company (CHESF) - Teresina agency - PI for the period from 01/12/2004 to 02/02/2011.

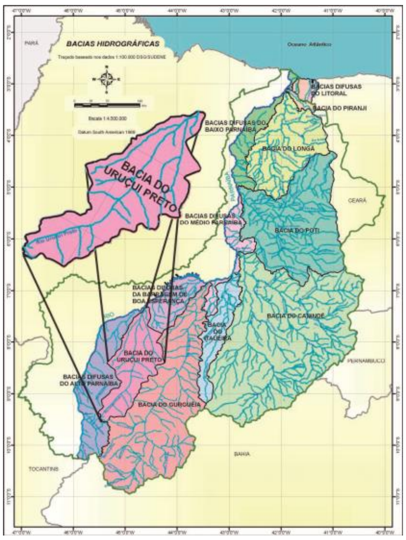

Figure 1- The catchment area of river Uruçuí Preto. Adapted for Medeiros (2013).

2.2 IPH II model

Tucci (1993) said that one of the objectives of IPHS II model is to improve understanding of hydrological processes and algorithms used in the simulation. The IPH II model is a conceptual model that simulates the rainfall-runoff process, with handling a minimum number of parameters, and is based on the following algorithms: Losses by evaporation and interception; separation of flow; propagation of surface and underground flows. The parameters that comprise the model are: Io - infiltration capacity for t = 0 (mmh^{-1}); Ib - minimum infiltration capacity (mmh^{-1}); h - decay parameter of infiltration into the soil (dimensionless); Rmax - maximum capacity of the interception tank (mm); Ksup - spread parameter of runoff (h); KSub - Parameter spread of groundwater flow (h); Tc - concentration time bowl (h); AIMP - impervious area of the basin Percentage (%).

2.3 Adjustment and calibration of the IPH II

The calibration process minimizes errors between the model output and observed data, the process becomes complicated due to the large number of non-measurable parameters that need to be estimated, based on Veith et al. (2010). This calibration can be by trial and error, or automatically. The WIN_IPH II version of IPH II model allows performing the automatic calibration of the model, besides the manual, using two numerical optimization methods: monobjetivo and multiobjective. The SCE-UA algorithm is used in monobjetivo calibration and MOCOM-UA algorithm is using the automatic multi-objective calibration. This version has features to promote better interface between the model and the user through the presentation of the results of different interfaces in the form of graphics and animations, according to Bravo et al. (2007).

Obtained precipitation amounts of rain gauges and features of the peculiarities of sub-basins, the parameters (Table 1) of the IPH II model were estimated in such a way that the flow at the point of Uruçuí and Jerumenha control if equiparasse with the observed values. The points located upstream of the river Uruçuí Preto is 180 and 230 km from its confluence.

Table 1- Configuration of IPH2 model

parameters	I_o (mm/h)	I_b (mm/h)	H	$R_{máx}$ (mm)	% Area waterproof	VBEIC* ($m^3/s/Km^2$)
Uruçuí	8	3	0,5	25	0,10	0,002
Jerumenha	11	5	0,5	28	0,10	0,02

* Flow specifies base at the beginning of the rain (m^3s^{-1} km^{-2}).

In principle the data used in the parameterization of the model were the literature by Germano et al. (1998), Brun and Tucci (2001) and Tucci (2005). To make the next data of the observed results Io ranged from 6-15 mmh-1, Ib between 2-20 mmh-1, constantly modified until the desired response (results equivalent to those observed). Considering that the infiltration decay parameter H in the ground is very sensitive, it was determined a constant value based on the values found in the literature. Because this parameter is dimensionless the adopted value was 0.5. So, it worked only Io leakage values and Ib percolation. The Rmax values were estimated between 1.4 <Rmax <33. The percentage of impervious area ranged from 0.10 to 0.20%, for a great length of the river basin is embedded in almost rural area. Finally, the values of the base flow specify at the beginning of the rain (VBEIC) were estimated to BHRUP are in the range of 0.002 to 0.02 $m^3s^{-1}km^{-2}$.

2.4 Medium-Mobile models

We used medium-low order furniture models q to smooth the output time series of the HPI model II and facilitate the analysis of the results, according to Box and Jenkins (1970).

3. Results and discussion

Figure 2 shows the observed daily average flow rates and estimated by the IPH II (softened by middle-furniture 5 and 10 days) for the city of Bom Jesus, under the BHRUP. They are making strong discrepancies between estimated and observed in 2009 and 2010. The model efficiency values ranged between 6.2 and 6.8 indicating moderate efficiency, especially in the representation of the observed peaks. It should be noted that the behavior of the estimated flow rates (softened by middle-furniture 5 and 10 days) follows the rhythm of the flow rates observed with gaps in their peaks.

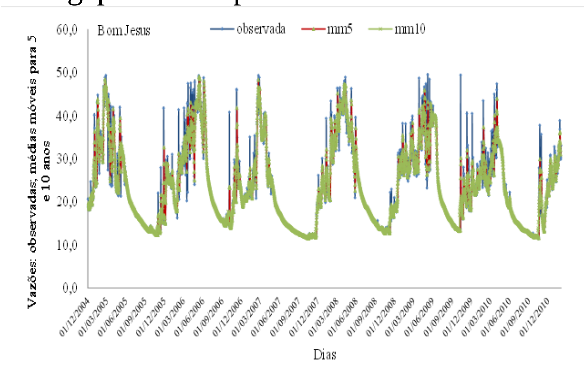

Figure 2 - Flow rates (m^3s^{-1}) observed daily averages and estimated by the IPH II (softened by middle-furniture 5 to 10 days) for the city of Bom Jesus.

In Figure 3 can be seen daily average flow rates observed and estimated by the IPH II (softened by middle-furniture 5 and 10 days) for the city of Cristino Castro. The analysis of this simulation follows the same criteria as the previous analysis, especially smaller gaps in relation to flow surges.

In Barreiras Piauí it is noted that the behavior of the estimated flow rates (softened by middle-mobile for 5 and 10 days following the variability of flows observed with small gaps in their peaks due to the influence of the local rains. Note also that the gaps are more pronounced for the series of 10-day moving average than for 5 days.

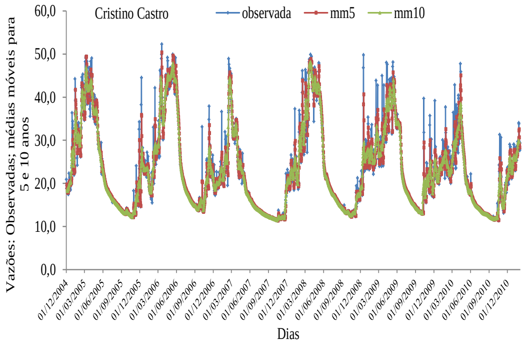

Figure 3 - Flows (m^3s^{-1}) observed daily average estimated by the IPH II (softened by middle-furniture 5 and 10 days) for the city of Cristino Castro.

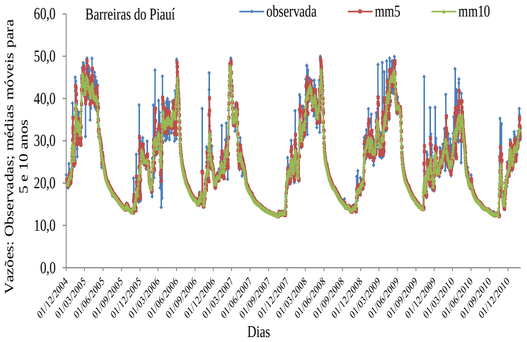

Figure 4 - Flow rates (m^3s^{-1}) observed daily averages and estimated by the IPH II (softened by middle-furniture 5 and 10 days) for the city of Barreiras Piauí.

In the municipality of Manoel Emídio the IPH II model simulations were similar to simulations of the municipality of Piaui barriers. The behavior of the average daily flow (softened by middle-furniture 5 and 10 days), Figure 5. The analysis is repeated for the municipality of Santa Filomena (Figure 6).

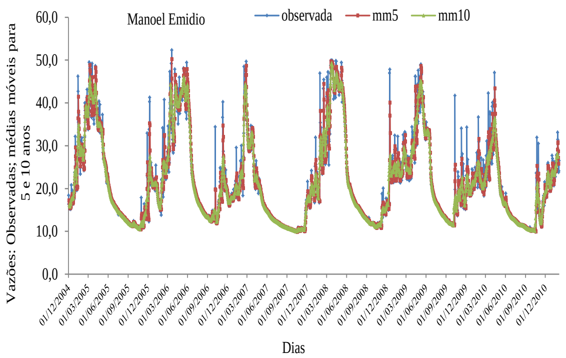

Figure 5 - Flows (m^3s^{-1}) observed daily averages and estimated by the IPH II (softened by middle-furniture 5 and 10 days) for the municipality of Manoel Emidio.

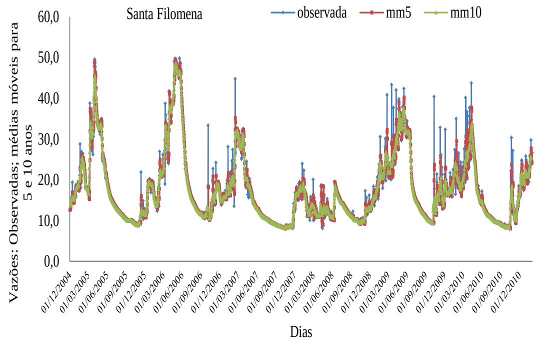

Figure 6 - Flows (m^3s^{-1}) observed daily averages and estimated by the IPH II (softened by middle-furniture 5 and 10 days) for the city of Santa Filomena.

4. Conclusions

The IPH II model fulfilled the task of simulating the average daily flow, but in three cases it was not very efficient to represent the peak (maximum and minimum) flow rates. Without loss of generality, this modeling can be used in basins with similar characteristics to those presented by BHRUP, especially if there are no requirements on the suitability of extreme values.

Additionally it was done a simulation of BHRUP with land use in 100% of pasture. In that case, there would be an increase in soil moisture as a result there would be increased flood peaks with more severe and frequent flooding.

On average the correlation coefficient between calculated and observed flow was around 0.95 and root mean square error 8.2.

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