Chapter

Hydrological Modeling in the Rio Conchos Basin Using Satellite Information

Paul Hernández-Romero, Carlos Patiño-Gómez, Benito Corona-Vázquez and Polioptro Martínez-Austria

Abstract

The hydrologic modeling is a useful tool for integrated water management in watersheds. Its construction generally requires precipitation information and different physical parameters related with a watershed. In Mexico, the availability of official rainfall information, which is reliable and sufficient, is a challenge today. In some areas, there is the right amount of information but of poor quality, while other locations have few climatological stations. However, using the tools of the Industrial Revolution 4.0, we have satellite information that can supply additional records that are not available in the network of climatological stations. Nevertheless, it is necessary to evaluate the quality and usefulness of satellite information, for which an inter-comparison exercise between sources of information is useful and sometimes necessary. An alternative to obtain updated satellite records is the CLIMATESERV database of the GLOBALSERV. The objective of this work is to present the analysis and the results obtained from the hydrological simulation corresponding to year 1981, considering as the case study area the upper Río Conchos basin. For the generation of rainfall time series, the database of the rapid exhaust of meteorological information was used in version III (ERIC III 3.2 by its Spanish acronym) and the CLIMATESERV database.

Keywords: hydrological modeling, Rio Conchos basin, satellite climate information, HEC-HMS, CLIMATESERV

1. Introduction

In the region where the Río Conchos basin is located, the water pressure (total volume of concession water/volume of renewable water) has risen 27% in the last 14 years, increasing from 50% in the year 2003 to 77% in 2017 [1, 2]. This pressure is associated with population growth, increased irrigation land, growing urbanization, water-body pollution, aquifer overexploitation, and climate change.

Taking into consideration the above, it becomes clear that current water management in the region is not responding to the expectations of use for human consumption, the environment, and international responsibilities.

Therefore, for future decision-making about water management in the region, appropriate tools and methodologies are needed. The modeling of the rain-runoff process, which can be supported by a relational data model, is a very useful tool for the integrated water management in hydrological watersheds. This model aims to determine the amount of water available and analyze in detail the rain-runoff process in the watershed, and, thus, know the availability in the tributaries and help the decision-making in relation to the distribution of water resources, the proper implementation of integrated water management, and compliance with international treaties in the region. The construction of a hydrological model generally requires precipitation information and different physical parameters of the watersheds. In Mexico, the availability of official rainfall information, reliable and sufficient, is a challenge today, because there are no updated records in some regions. In some areas, there is the right amount of information but with poor quality, while other locations have few climatological stations.

On the other hand, using the tools of the Industrial Revolution 4.0, we now have satellite precipitation information that can reinforce and even supply the lack of information available in the network of climatological stations. However, it is necessary to evaluate the quality and usefulness of satellite information, for which an intercomparison exercise between sources of information is very useful and sometimes necessary. An alternative to obtain updated satellite records is the CLIMATESERV database of the GLOBALSERV. This database is made up of different satellite data sources and terrestrial source records.

The objective of this work is to present the analysis and the results obtained from the simulation corresponding to year 1981 of the rain-runoff process using the HEC-HMS software, considering the Río Conchos as the case study area—P. de la Colina subbasin located within the Río Conchos basin.

2. Methodology

2.1 Data collection

2.1.1 Geographic information

The geographic information of the basin was obtained in scale 1:50,000 and 1:250,000, which are common scales that manage the official dependencies in Mexico. This information is available in files with .shp extension (*Shapefile*) and in raster format for digital elevation models (DEM), which are located in the Lambert Conformal Conic projection coordinate system (CCL ITRF 1992), which uses the Datum International Terrestrial Reference Framework 1992 (D_ITRF_1992). A very complete relational data model was created including the most relevant base geographic and historical information compiled in the rio Bravo/Grande basin.

2.1.2 Climatological information

For the generation of rainfall time series, two sources were considered: one of them was the database named ERIC III that contains the meteorological information recorded by terrestrial climatological stations. The second source used was the CLIMATESERV database. The ERIC III database contains official information recorded by climatological stations from the National Water Commission (CONAGUA by its acronym in Spanish). The average daily precipitation was calculated with the help of the program *ArcGIS* 10.4, using the method of the *Thiessen polygons*. On the other hand, CLIMATESERV contains information from multiple satellite data sources and terrestrial observations, which combine the information to create rainfall historical series. **Figure 1** shows the average daily precipitation

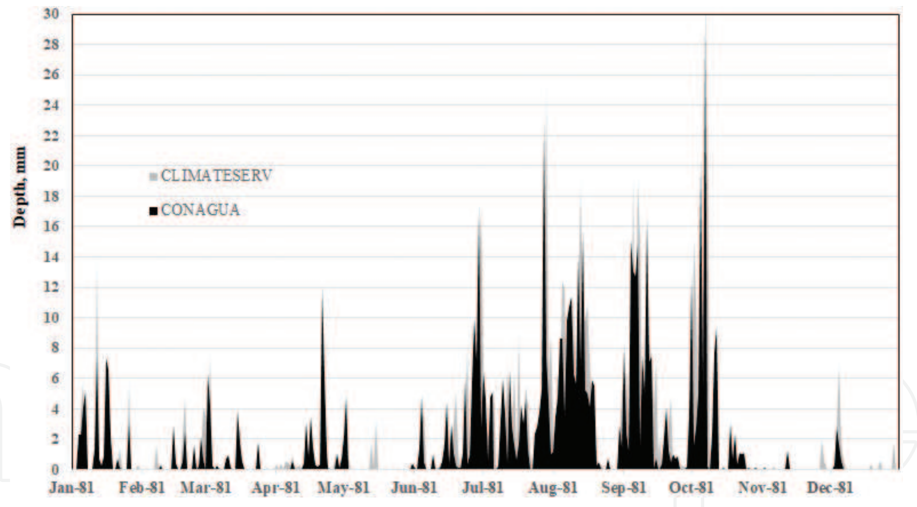

Figure 1.
Precipitation time series of the ERIC III and CLIMATESERV of the year 1981.

of year 1981 from the two-database mentioned, which served as the main input parameter for the hydrological model. It is worth mentioning that the difference in millimeters of rainfall of the time series from the two databases is 11.15 mm that is equivalent to 1.63% of inconsistency.

2.1.3 Hydrometric information

Hydrometric information was obtained from the National Surface Water Data Bank (BANDAS by its acronym in Spanish) of the CONAGUA. In addition, naturalized flow information from the Texas Commission on Environmental Quality (TCEQ) was used [3]. The study area contains only one hydrometric station, 24,400-Llanitos, but it is located in the upper part of the basin, so the information could not be used. Thus, it was determined to use the hydrometric station 24077-Colina and the hydro-climatological station 8055-La Boquilla, which are located at the exit of the watershed. **Figure 2** shows the location of hydrometric stations in the study basin, and **Figure 3** shows the average daily runoff of year 1981 of the stations mentioned, which was used for calibrating the hydrological model.

2.1.4 Physiographic information

The area of the Río Conchos—P. de la Colina watershed is 20,814 km^2, which was obtained with the help of the software *ArcGIS* taking as base layer the file.shp of hydrological subregions from the CONAGUA. The concentration time (T_c) was calculated using the *Kirpich* equation, which relates the length (L_i) and the slope (S_i) of the main channel. The *Taylor-Schwarz* method was used for the slope calculation. According to the U.S. Department of Agriculture [4], the relationship between the T_c and the peak time (T_p) is equal to $T_p = 0.6T_c$. The curve number (CN) was calculated with the soil conservation service method (SCS), which is defined by the hydrological soil groups (HSG), soil treatment, type of coverage, and the antecedent moisture conditions (AMCs).

2.2 Construction of the HEC-HMS model

After gathering the necessary information to enter into the hydrologic model, the model was built to simulate the rain-runoff process of Río Conchos-P. de la Colina with the HEC-HMS software version 4.2.1 using the method of

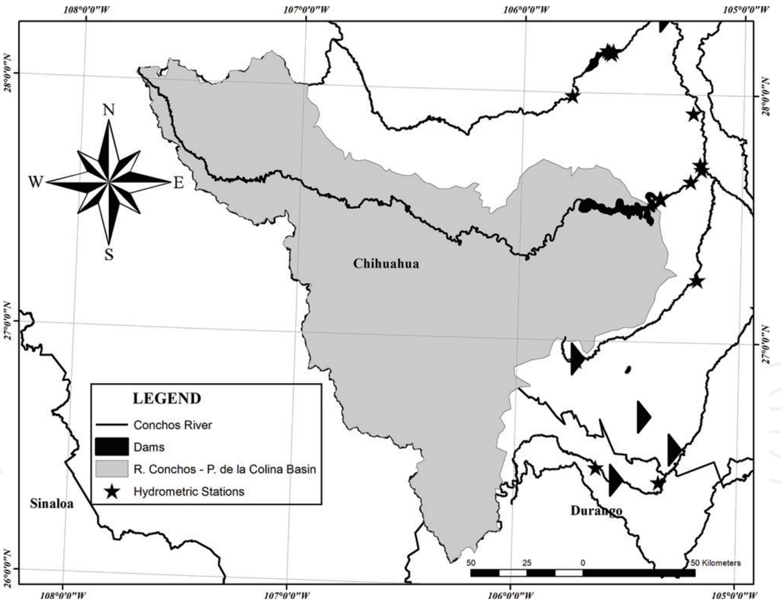

Figure 2.
Location of hydrometric stations.

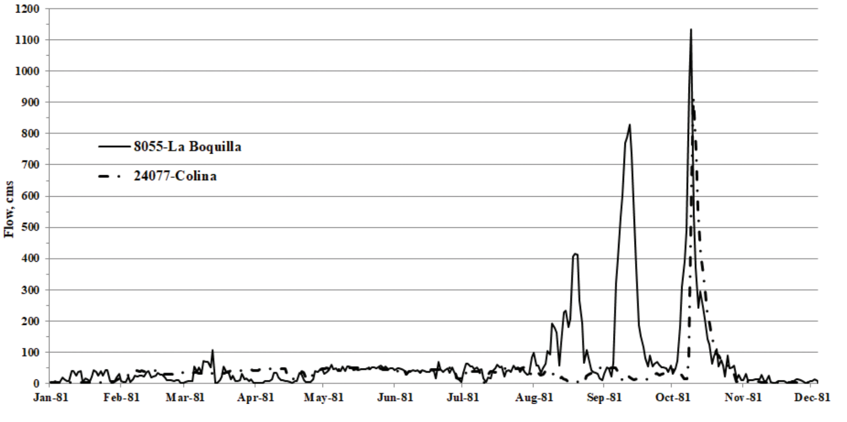

Figure 3.
Average daily runoff of year 1981.

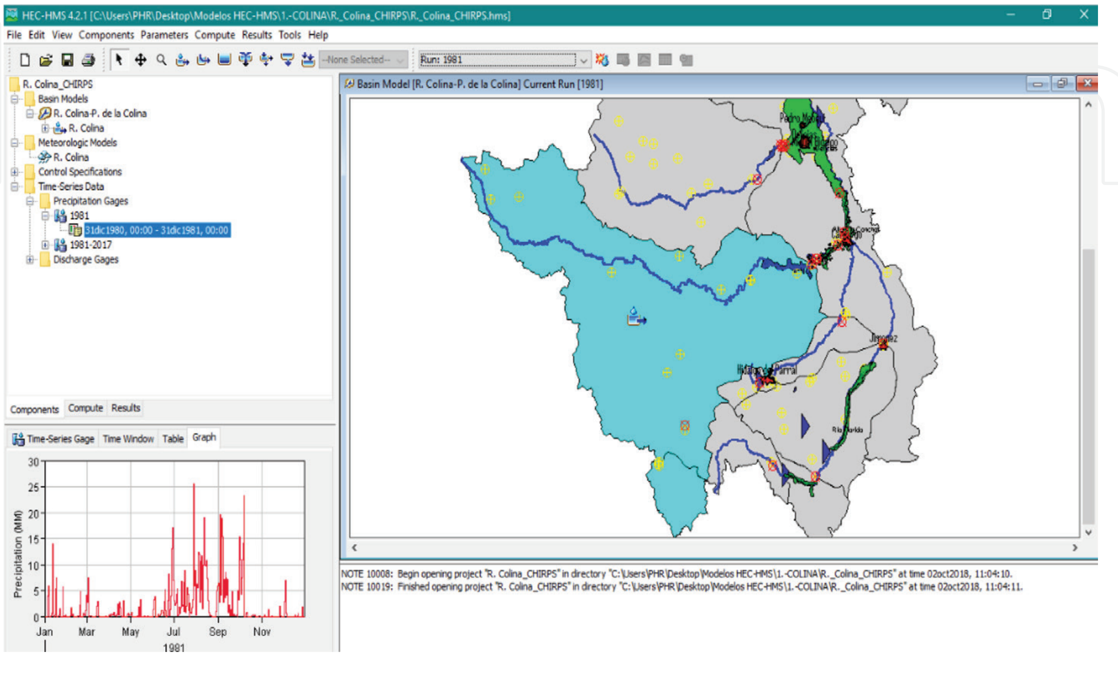

Figure 4.
Scheme of the HEC-HMS hydrological model of the Río Conchos-Presa de la Colina subbasin.

transformation of the SCS Unitary Hydrograph (**Figure 4**). The data were input into the software in an organized manner taking into consideration its main components: basin model, meteorological model, control specifications, and time-series data [5]. The simulation of the hydrological model used a period of 365 days, from January 1 to December 31, 1981, establishing a daily interval. The time series of the different databases were captured manually, specifying the increment in millimeters (mm).

3. Results, calibration, and statistical evaluation

3.1 Results

Figure 5 shows the output hydrograph of the hydrological simulations with the two sources of precipitation information mentioned above.

3.2 Calibration

The calibration of the model involved a quantitative assessment of the hydrological response of the subbasin. This process was done by comparing the observed hydrograph with the simulated hydrograph. This is essential for the evaluation of the model, to compare the distribution and variations of the data [6]. **Figure 6** shows the result of this comparison.

3.3 Statistical evaluation

The performance of the results of the model was assessed with several statistic models, such as the coefficient of determination, correlation, standard deviation of observations (RSR), and efficiency of the Nash-Sutcliffe (NSE). **Table 1** shows the results of the statistical evaluation of the simulations versus the observed historical information.

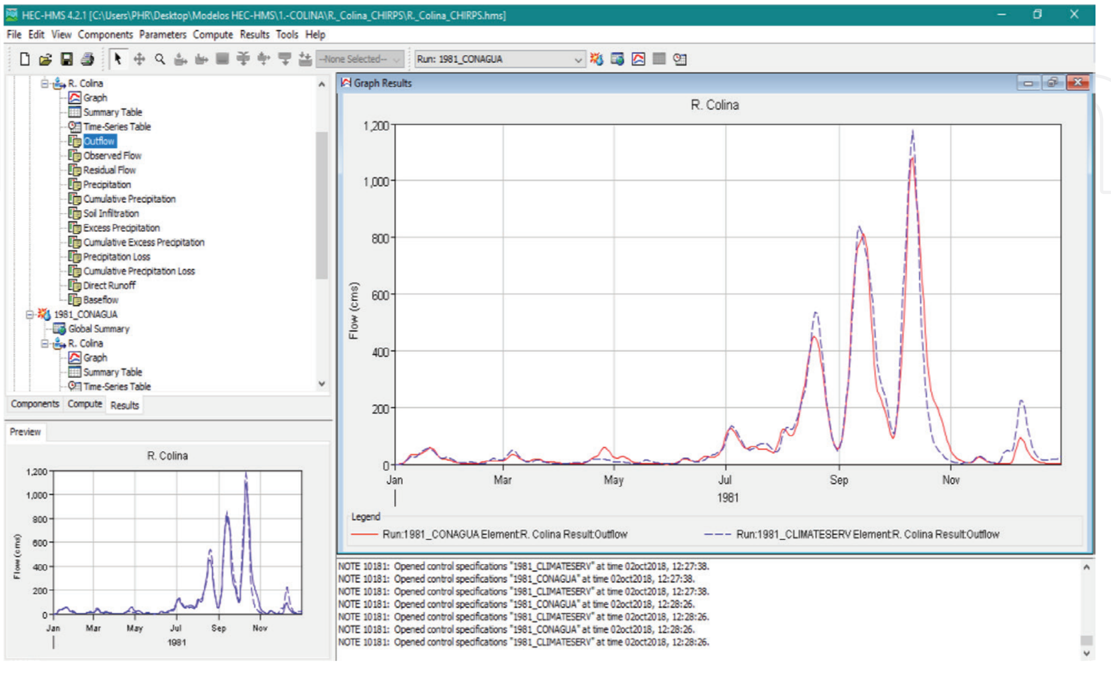

Figure 5.
Output hydrographs of hydrological model HEC-HMS: CONAGUA (red) vs. CLIMATESERV (blue).

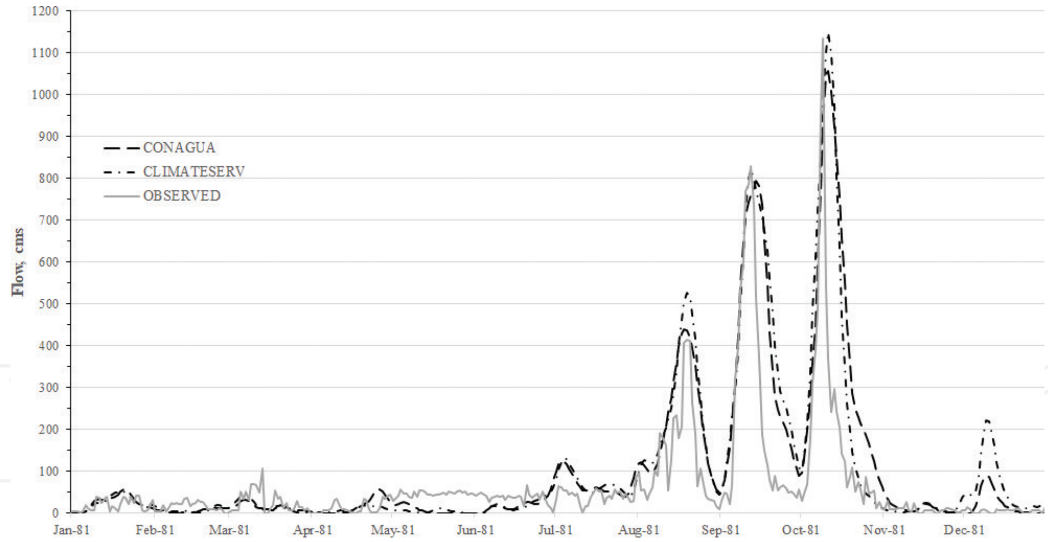

Figure 6.
Hydrographs simulated vs. hydrographs observed.

Results	Observed	Simulated CONAGUA	Simulated CLIMATESERV
Q_{max}	1,135.29	1,055.40	1,145.80
Q_{max}	09/10/1981	11/10/1981	11/10/1981
Error, Q_{max}	—	7.04%	−0.93%
Mean	67.92	104.28	107.71
Stan. Dev.	138.13	196.13	203.57
r	—	0.81	0.82
r^2	—	0.66	0.67
RSR	—	0.54	0.59
NSE	—	0.71	0.65

Table 1.
Summary of statistical results of the evaluation of the model.

4. Discussion and conclusions

The hydrological model created using the HEC-HMS software simulated very well the rain-runoff process of the Río Conchos-P. de la Colina. The precipitation information and different physical parameters of the watershed came from different sources. Talking about the precipitation input parameter, time-series were generated based on two sources of information: the first one with official information from climatological stations reported by the CONAGUA, and the second source with information from the CLIMATESERV database of the GLOBALSERV, which combines multiple satellite data sources and observations terrestrial. Quality and usefulness of the satellite information of precipitation were evaluated, by means of an intercomparison exercise between the time series coming from the two sources, obtaining a difference of 1.63% between them.

Based on this analysis, the result is a hydrological simulation model of the subbasin related to year 1981. A benchmark analysis of results and a statistical evaluation of the model were carried out. The analysis indicated a good behavior of the model versus the historical information observed, since the adjustment of the distribution and variation of the output flow were good. According to Moriasi et al. [7], the statistical evaluation of the model indicated a good performance or behavior of the CLIMATESERV database, with respect to the information registered *in situ*. Based on these results, it can be established that satellite records are a good alternative to reinforce or supplement the lack of information available in the network of climatological stations in Mexico.

Acknowledgements

We acknowledge the Universidad de las Americas Puebla and the UNESCO-UDLAP chair in hydrometeorological risk for all the support and facilities provided for the achievement of this work.

Author details

Paul Hernández-Romero, Carlos Patiño-Gómez*, Benito Corona-Vázquez and Polioptro Martínez-Austria
Department of Civil and Environmental Engineering, Universidad de las Américas Puebla, San Andrés Cholula, Puebla, México

*Address all correspondence to: carlos.patino@udlap.mx

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