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Hydrological modeling of a tropical basin with SWAT: A study case of Cauto River, Cuba

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Introduction

Water issues in Cuba

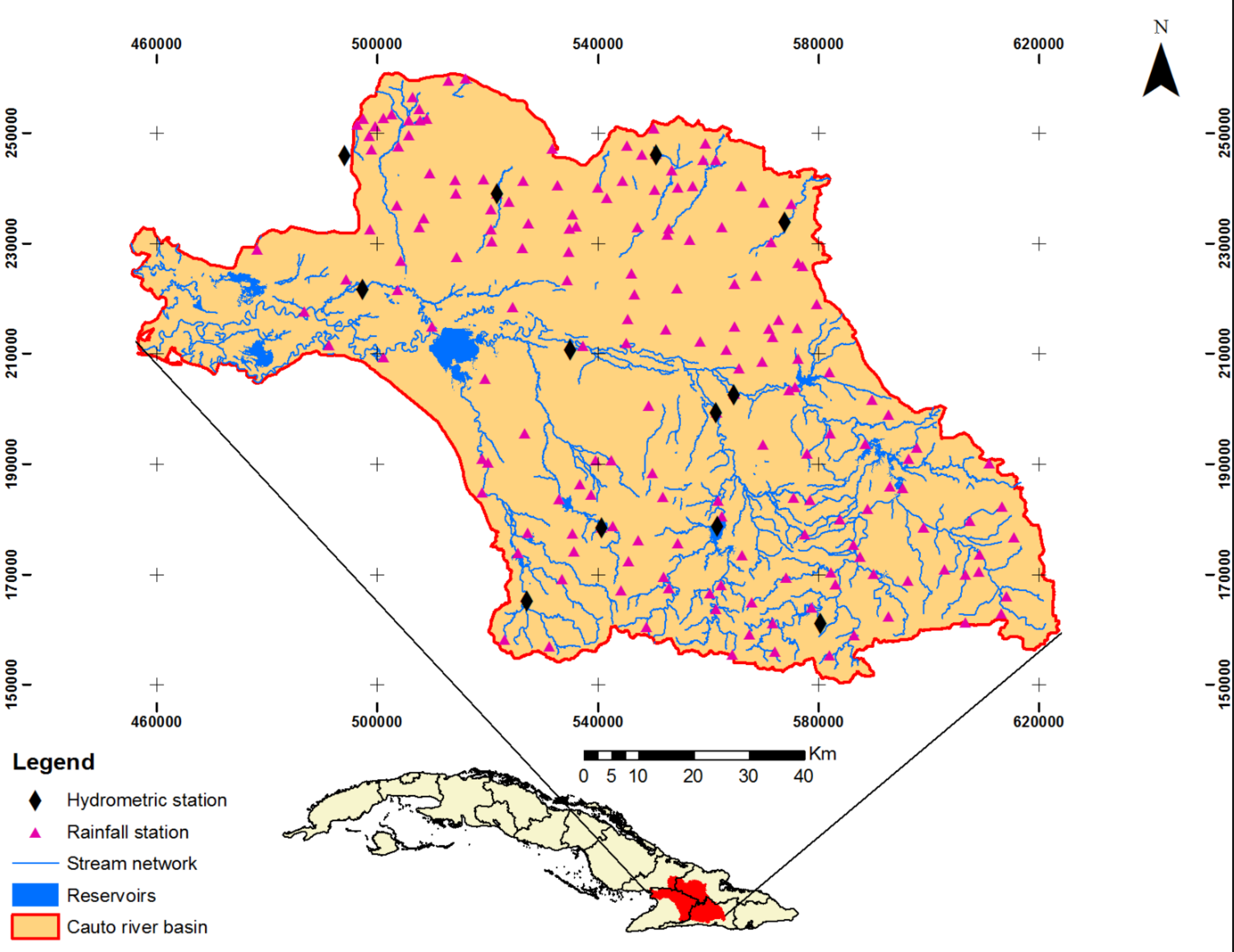
- Cuba is a country that has been quite vulnerable to hydrological extreme events.
- Hydrological modeling in the region has shown to bring important information for decision makers.
- Cuba is prone to an increase in number of extreme events due to climate change.
- El Cauto river basin is one of the biggest, largest and most important in the country. 10% of the country lives in this region and it is inundated every year.

- THERE IS A NEED TO UNDERSTAND THE HYDROLOGICAL CHANGES DUE TO CLIMATE CHANGE

El río Cauto cerca de Guamo Embarcadero, Cuba.

Cauto River Basin

✓ **Area**: 9540 Km^2
✓ Climate**:** HumidTropical
✓ **Annual Rainfall:** 1350 mm
✓ **Type of basin**: Exoreic (drains to the sea)
✓ **Type of soils**: Vertisols, Pardos with carbonates (Deep cracks in the dry season)
✓ **Landuse:** Agriculture Evergreen forests



Objetive

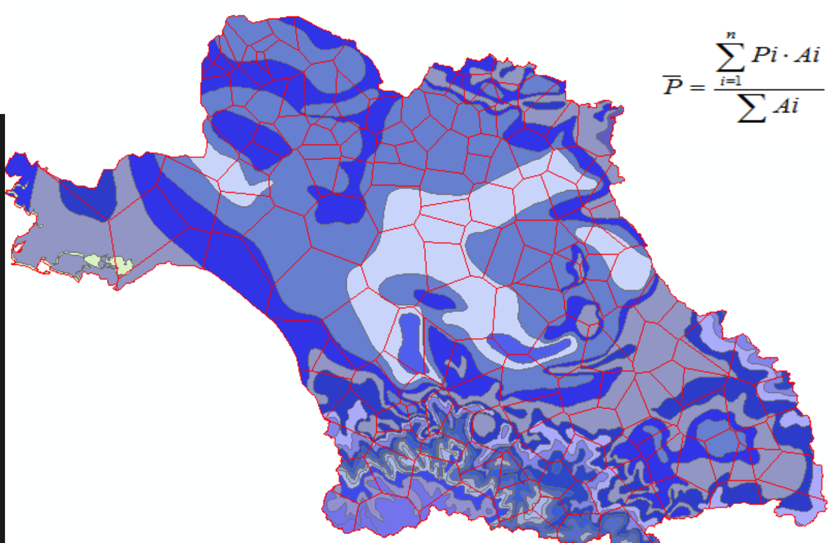
The objective of this study was to have a good model representation such that results from climate models can be used to assess wáter availability and extreme events

This first part of the CC research is dedicated to implement a SWAT (Soil and Water Assessment Tool) model to simulate the water resources in the Cauto River. We expect that this preliminary results will aid the study of the current responses of the basin to extremes as well as to provide a basis to characterize the properties of the basin.

Methodology

Hydrological Analysis

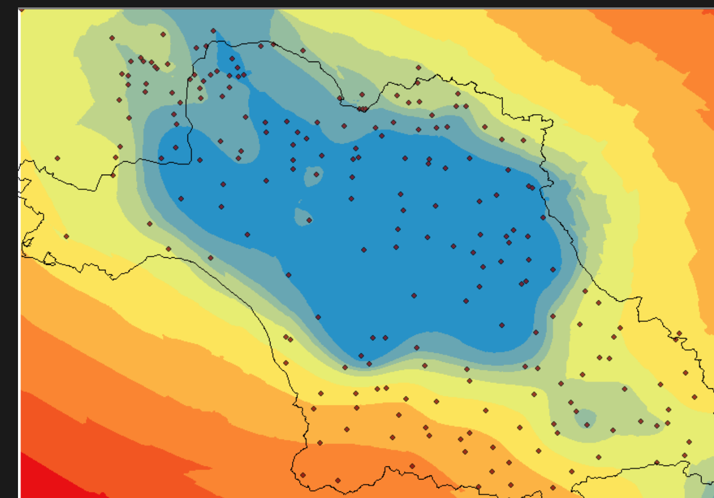
- Generalization of information

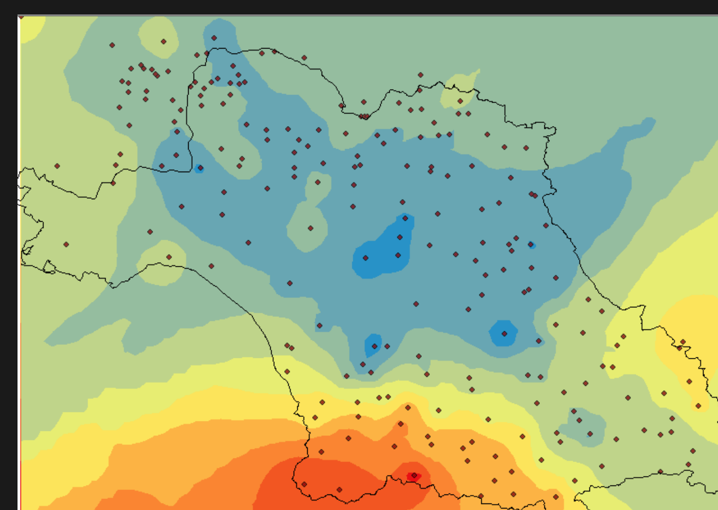


$$\overline{P} = \frac{\sum_{i=1}^{n} Pi \cdot Ai}{\sum Ai}$$

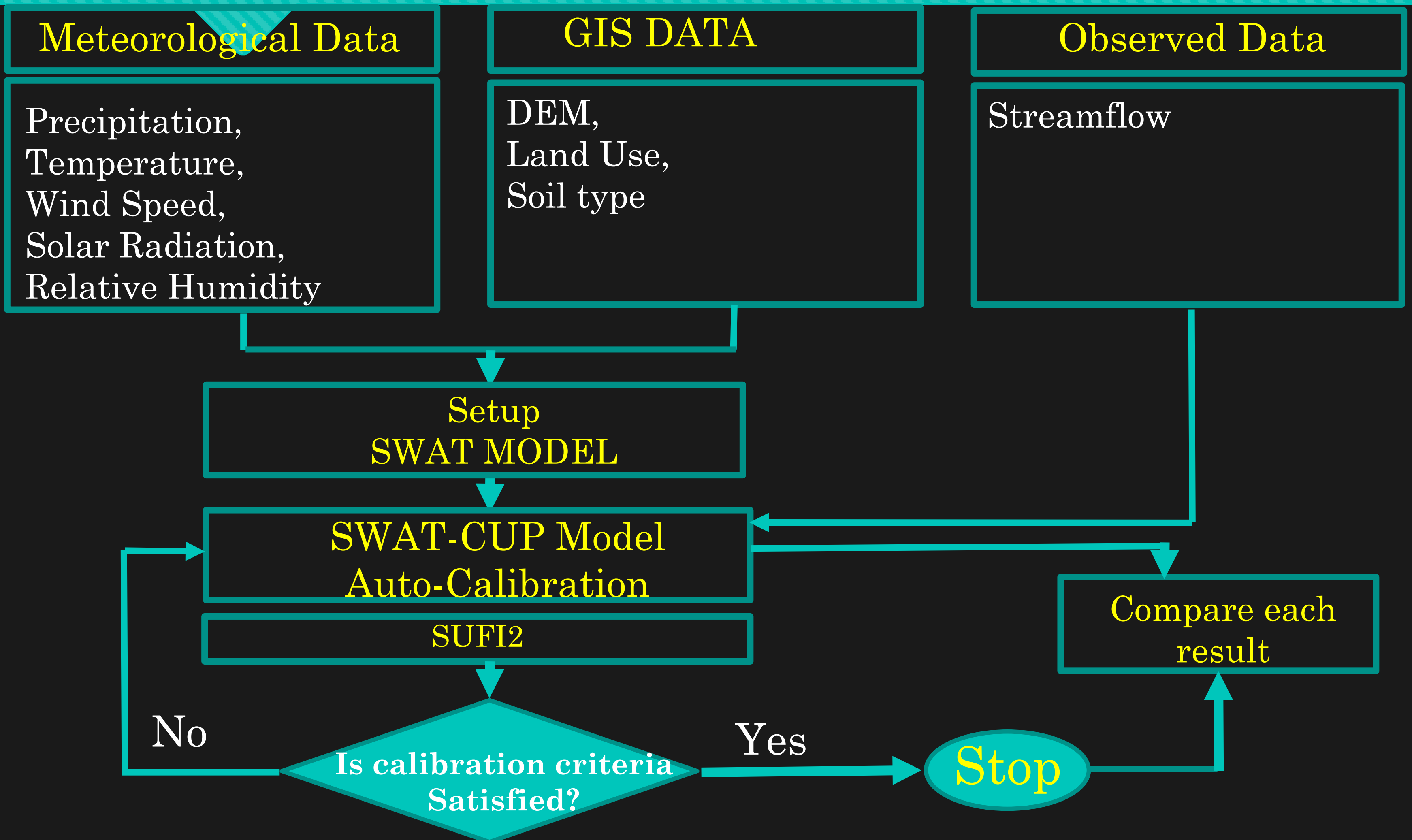
- Hydrometeorological Information: Interpolated P Series

127 Pluviometric stations





SWAT Procedure



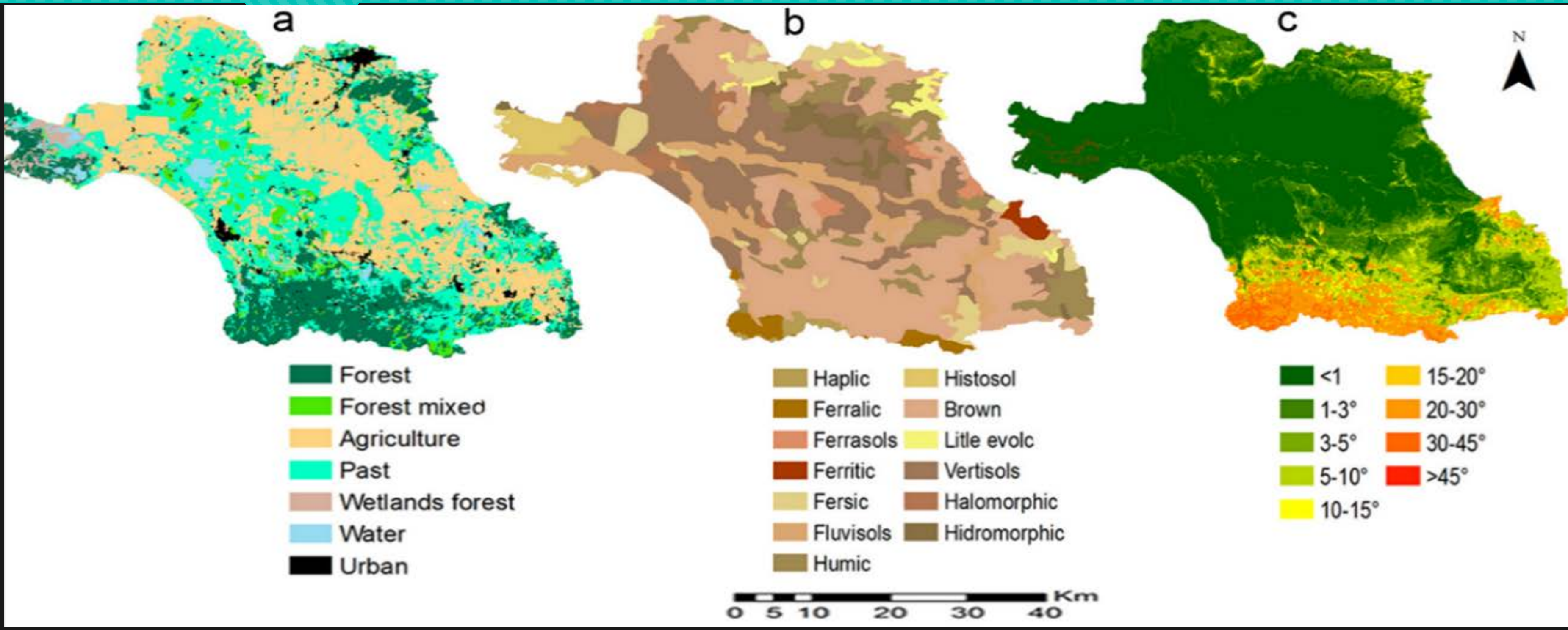
Input and Measured Data

- **Data set for SWAT Model**

Data type	Source	Scala/ Periods
DEM	Cuban Environment Agency	25 m
Soil	Cuban Soils Institute	1:25000
Land use	Cuban Soils Institute	1:25000
Weather	Cuban Institute of Meteorology and the Enterprise Group for Hydraulic	1996-2010

GIS inputs Data

. The Cuban Soils Institute provided land use coverage (1: 100,000) , and 7 categories

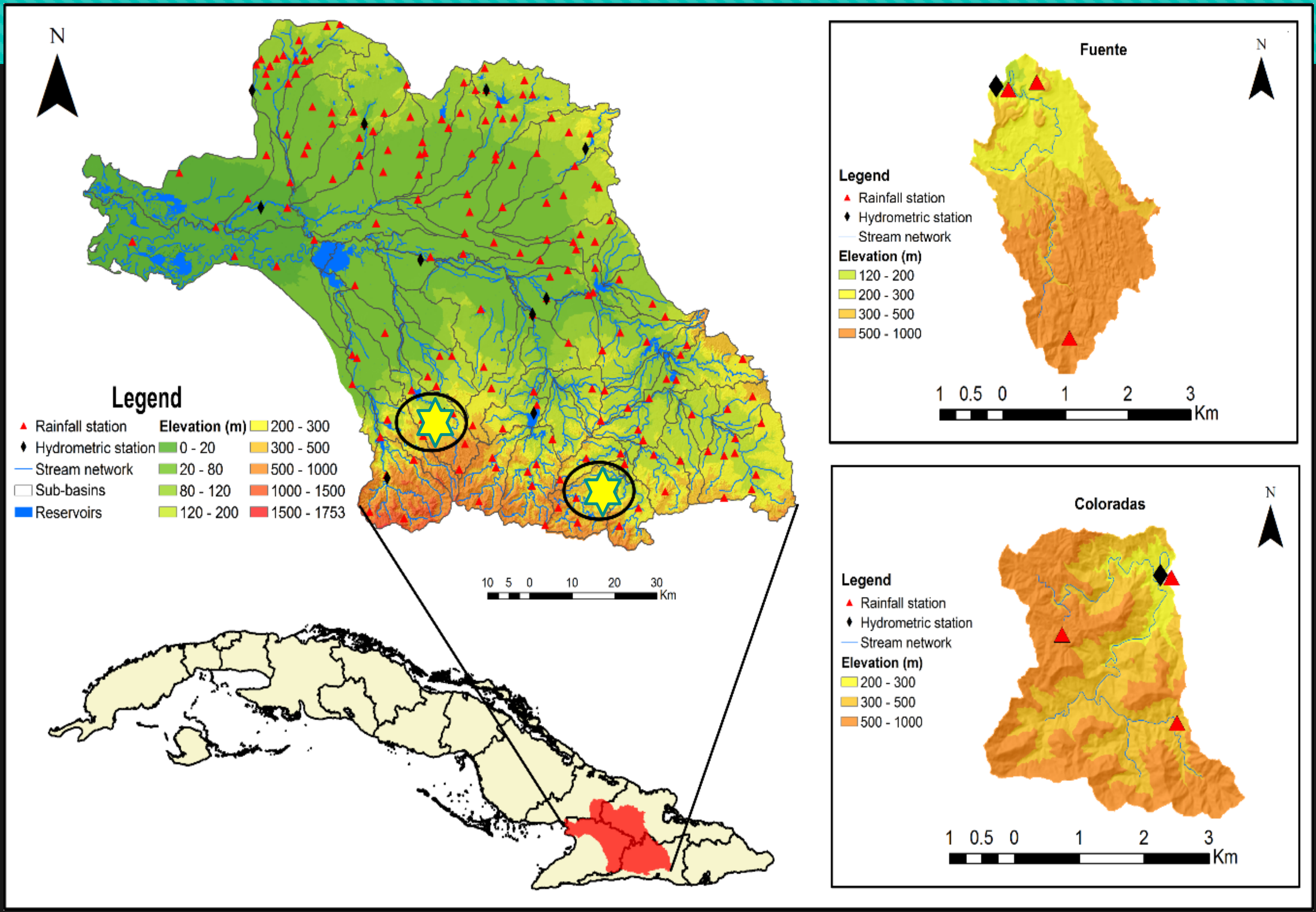


a) Landuse b) Soil c) Slope

The topography was based on the Digital Elevation Model (DEM) obtained from the studies of danger, vulnerability and flood risks (AMA, 2010) with a resolution of 15 × 15 m. After calculating the drainage map we obtained 82 sub-basins (similar size)

Calibration Points

La Fuente sub-basin and Las Coloradas sub-basin



SWAT-CUP
(SWAT Calibration Uncertainty Program)

Algorithmo

SUFI2 (Abbaspour, et al., 2007) : **S**equential **U**ncertainty **Fi**tting the parameter uncertainty accounts for all sources of uncertainties such as uncertainty in driving variables (e.g., rainfall), conceptual model, parameters, and measured data.

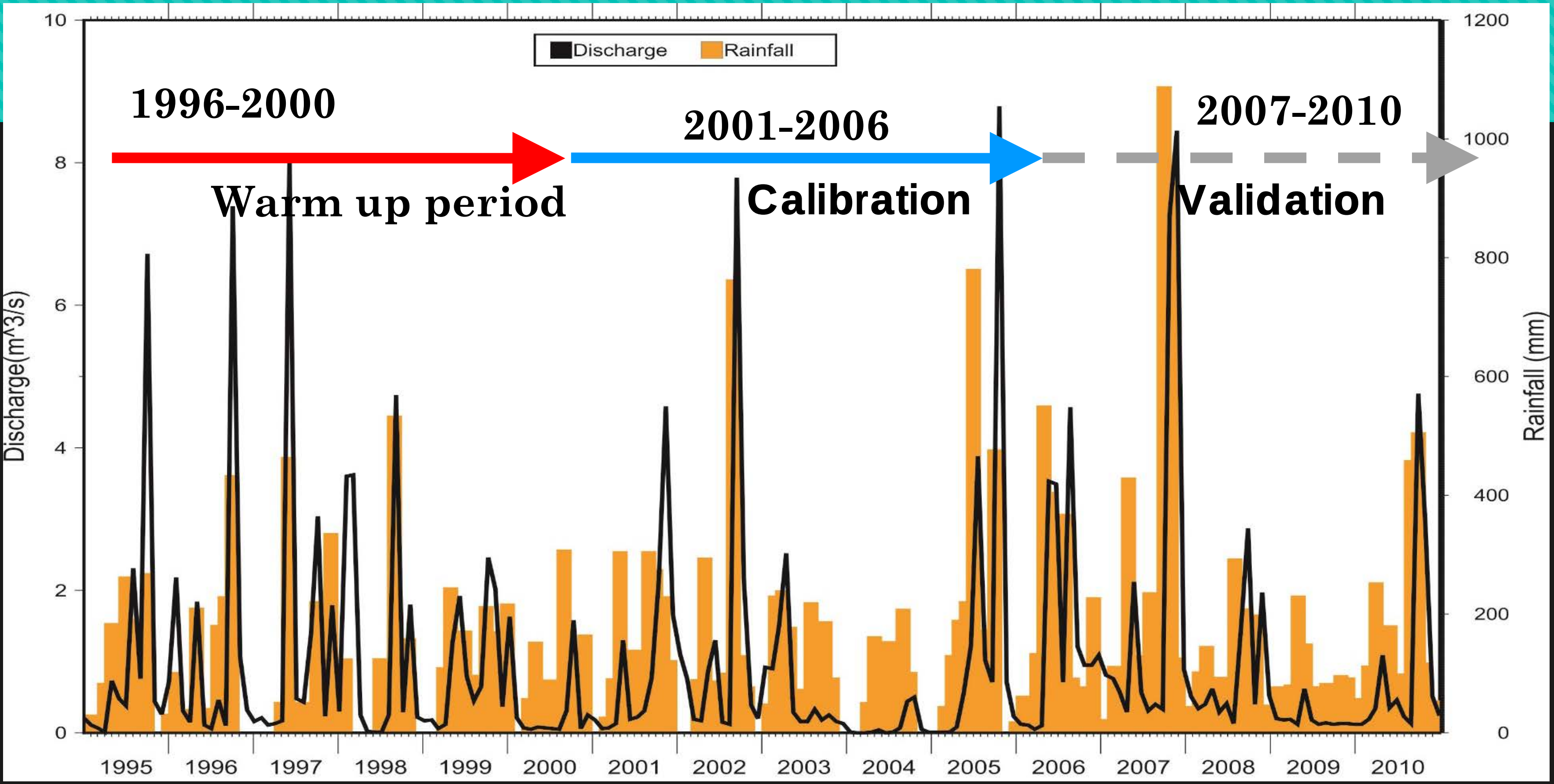
- ✓ Sub-basins La Fuente and Las Coloradas
- ✓ 3 runs, each 500 iterations
- ✓ Start with 17 parameters
- ✓ Observed stream flow (m^3/s)
- ✓ Monthly time step

Sensitivity Analysis (SA)

✓ **Latin Hypercube (LH) –One-factor-At-a-Time (OAT)**

- A parameter **SA** provides insights on which parameters contribute most to the output variance due to input variability. In this study,we performed an **LH-OAT** SA.
- A ranking of parameter sensitivities was obtained after 300 model runs. The 17 parameters with highest sensitivities were selected for model calibration
- Using the SA results calibrated parameters for hydrology

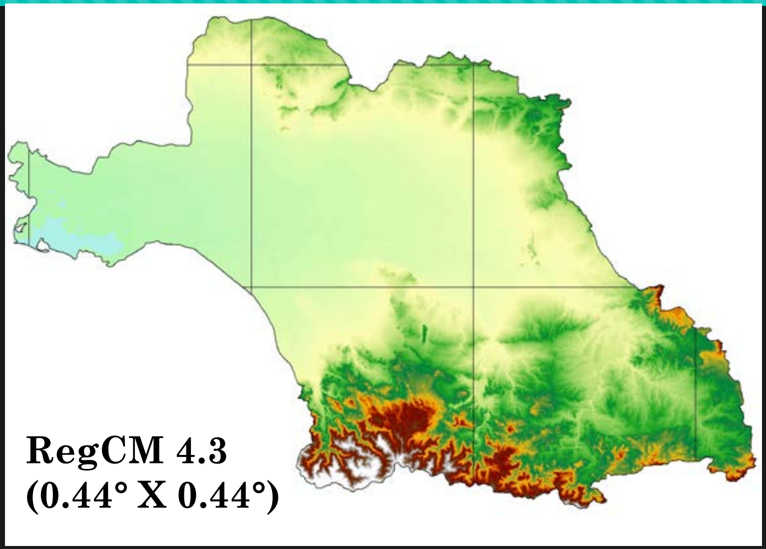
Calibration and Validation



LH-OAT (300 runs)   SWAT-CUP(SUFI 2, 1500 runs)

Climate change scenario

Regional Climate (RegCM 4.3)

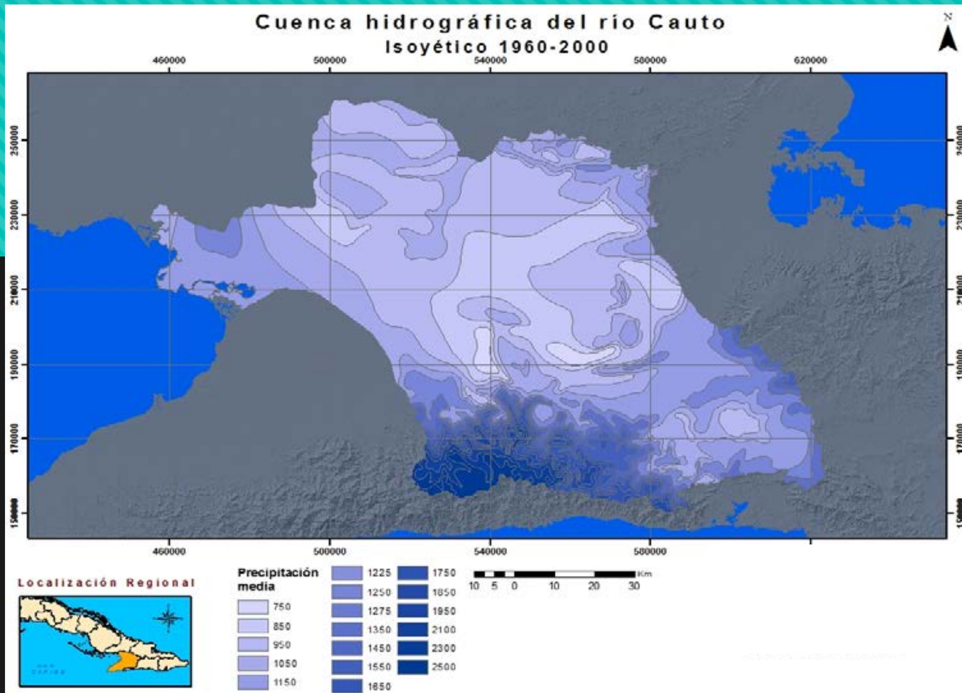


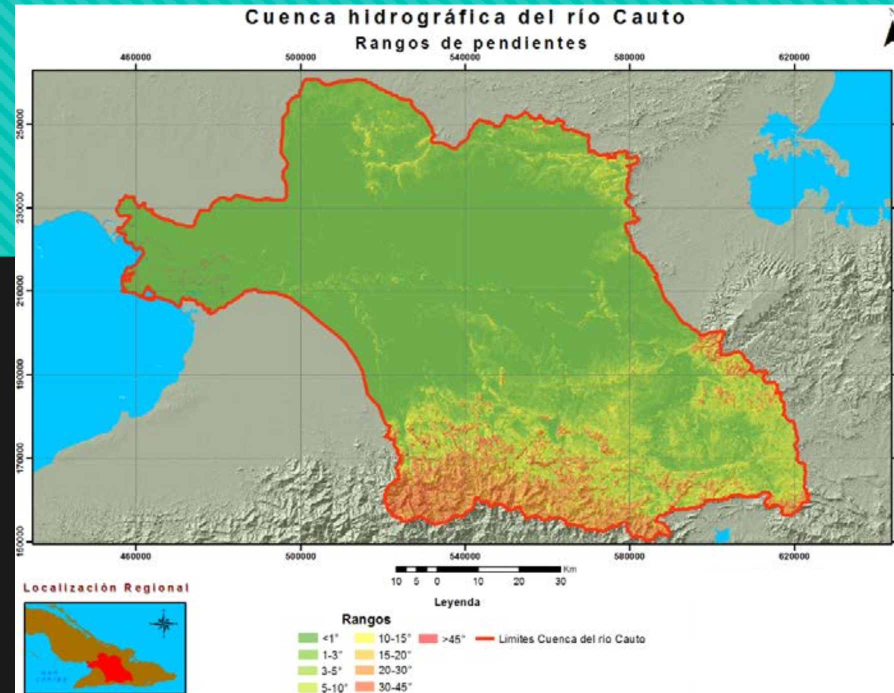
Model	RegCM 4.3
Center	Earth System Section. ICTP
Grid size	50 Km X 50 Km
Baseline	1970-2000
Scenario	RCP 8.5
Country	Cuba
Forced by	HagGEM2-ES
Variable	Precipitation and Temperature

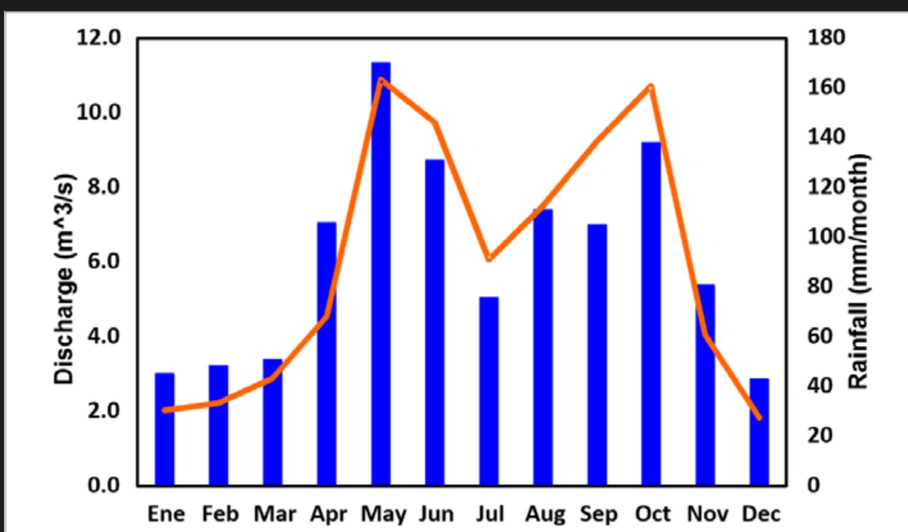
- ✓ The model reproduces the spacial and seasonal
- ✓ Patterns of precipitation over the region.
- ✓ Regional circulations are well reproduced

Results and discussion

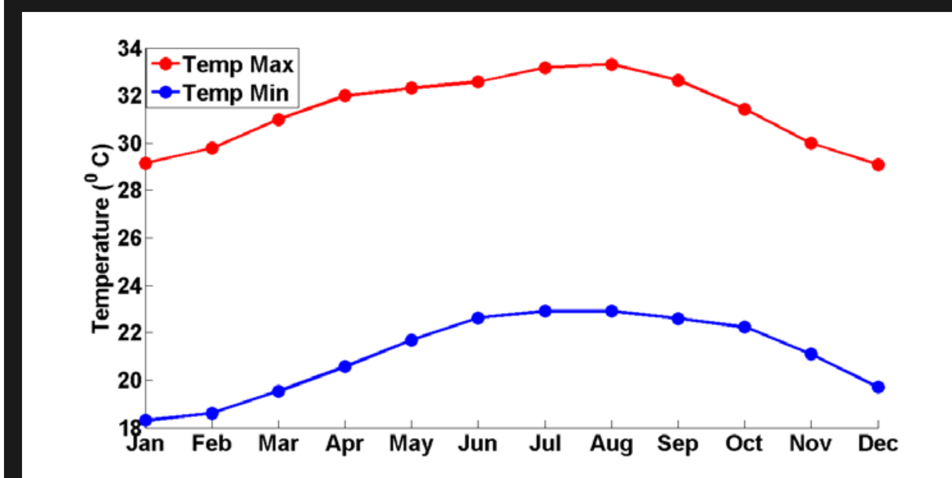
Hydrological Analysis







LA FUENTE (Station)



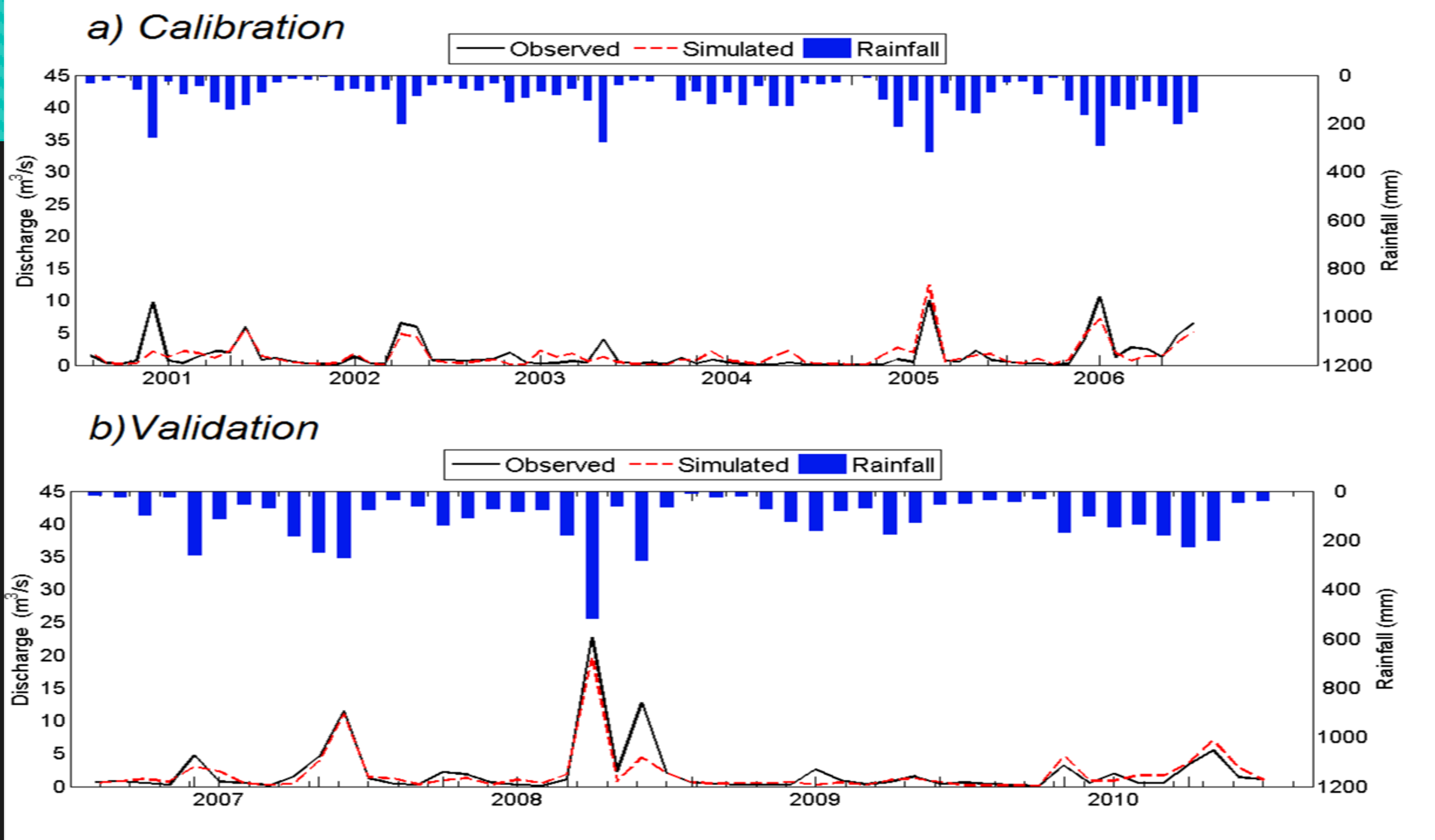
Model Performace

- Sensitivity analysis and auto-calibration:

			La Fuente	Las Coloradas
Parameter	Description	Range	Best Value	Best Value
CN2	U.S. Soil Conservation Service curve number for soil moisture condition II	-0.3-0.3	-0.17	-0.08
ALPHA_BF	Baseflow recession coefficient (days)	0-1	0.31	0.85
GW_DELAY	Delay time for aquifer recharge	5-500	111	482
GWQMN	Threshold water depth in the shallow aquifer for base flow (mm)	0-2000	1718	1671
GW_REVAP	Groundwater "revap" coefficient	0.02-0.2	0.09	0.17
ESCO	Soil evaporation compensation factor	0-1	0.67	0.34
CH_N2	Manning's "n" value for the main channel	0-0.3	0.18	0.16
CH_K2	Effective hydraulic conductivity in main cannel alluvium	5-130	21.27	6.30
ALPHA_BNK	Baseflow alpha factor for bank storage	0-1	0.43	0.73
SOL_AWC	Soil available water capacity	-0.3-0.3	-0.01	0.20
SOL_BD	Moist bulk density	-0.3-0.3	-0.13	-0.14
SOL_K	Saturated hydraulic conductivity	-0.3-0.3	-0.14	-0.17
OV_N	Manning's "n" value for overland flow	0.01-30	13.9	0.13
Lat_TTIME	Lateral flow travel time	5-180	6.93	134
REVAPMN	Threshold depth of water in the shallow aquifer for revap (mm)	0-1000	728	716
SURLAG	Surface runoff	0.1-24	13.22	17.65
EPCO	Plant uptake compensation factor	0-1	0.74	0.69

Model Performance

- Monthly calibration and validation (La Fuente)

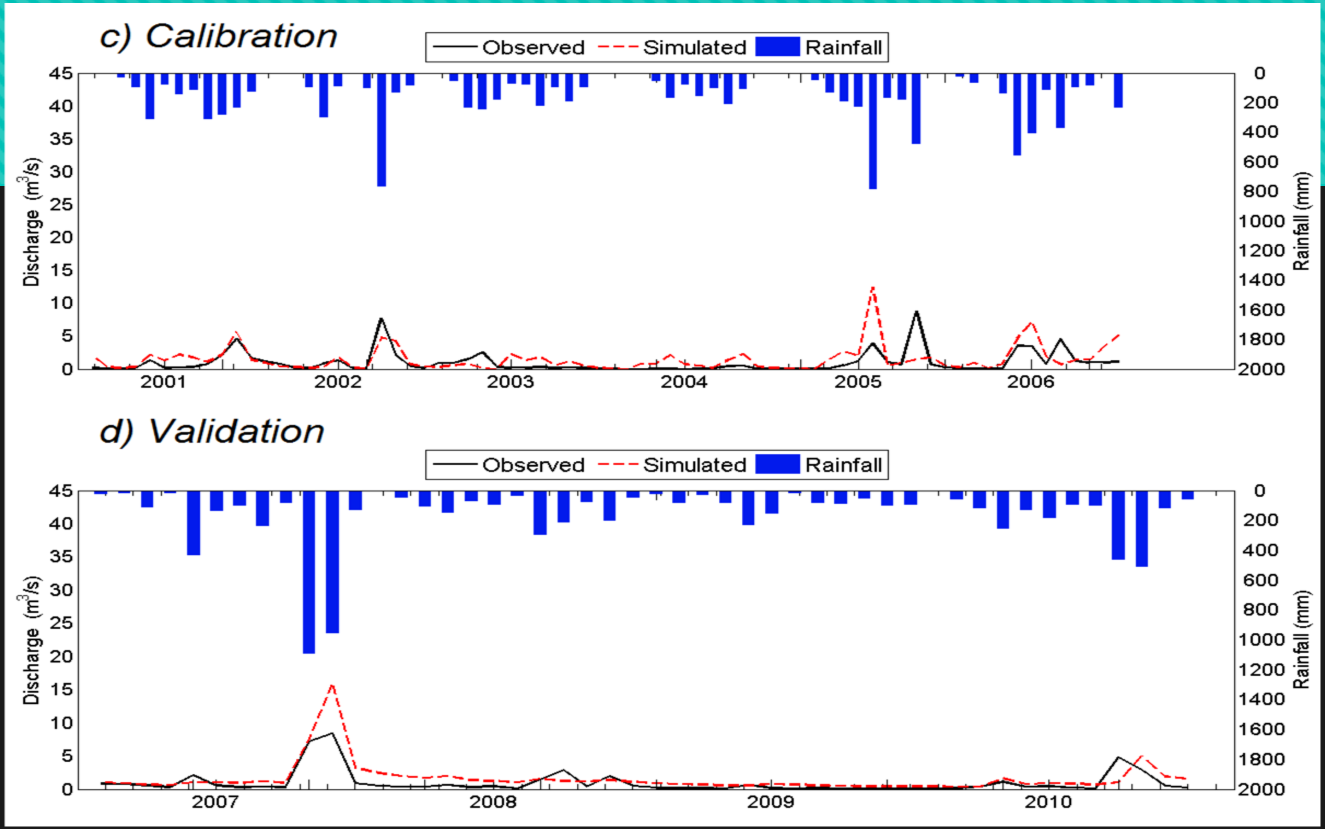


Sub-basin		Calibration (2001-2006)			Validation (2007-2010)		
		NSE	R^2	PBIAS	NSE	R^2	PBIAS
La Fuente		0.67	0.67	-2.8%	0.85	0.86	9.3%
		"Good"			"Very Good"		

(Moriasi et al., 2007)

Model Performance

- Monthly calibration and validation (Las Coloradas)

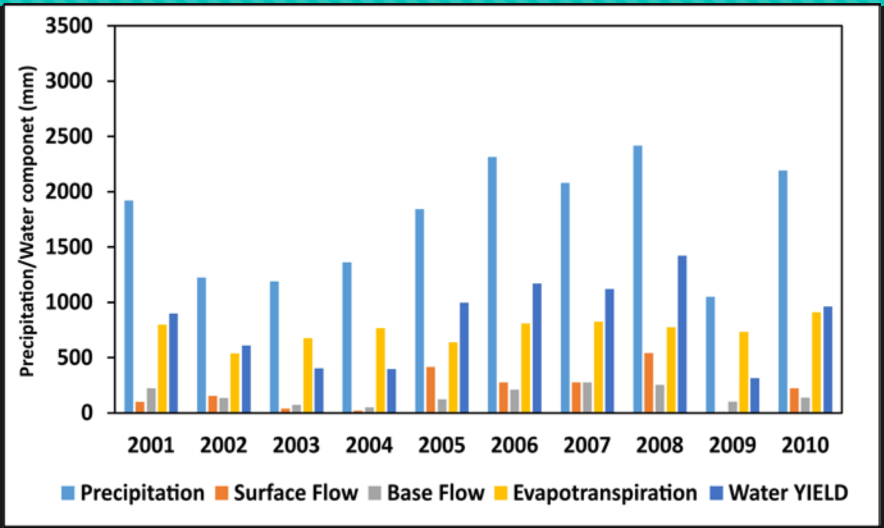


Sub-basin		Calibration (2001-2006)			Validation (2007-2010)		
		NSE	R^2	PBIAS	NSE	R^2	PBIAS
Las Coloradas		0.71	0.71	-1.6%	0.63	0.75	-9.7%
		"Good"			"Good"		

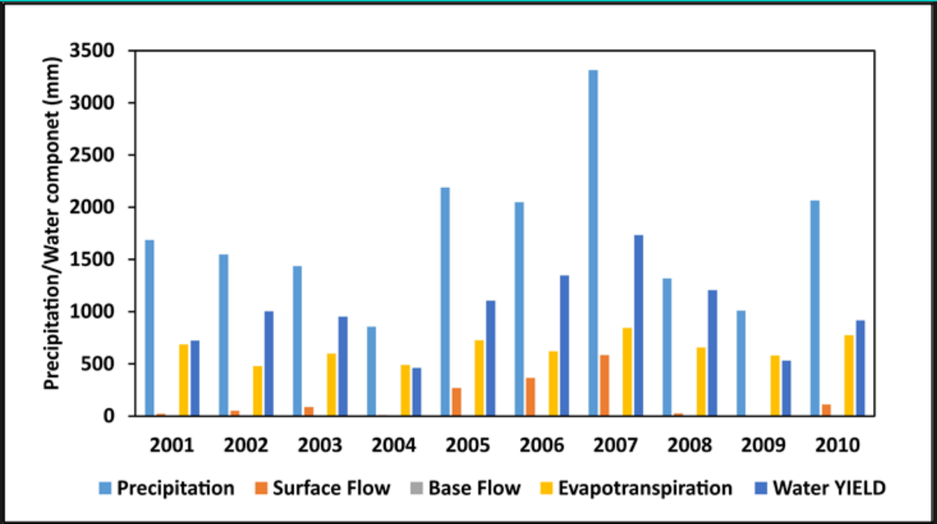
(Moriasi et al., 2007)

Water Balance

La Fuente Sub-basin

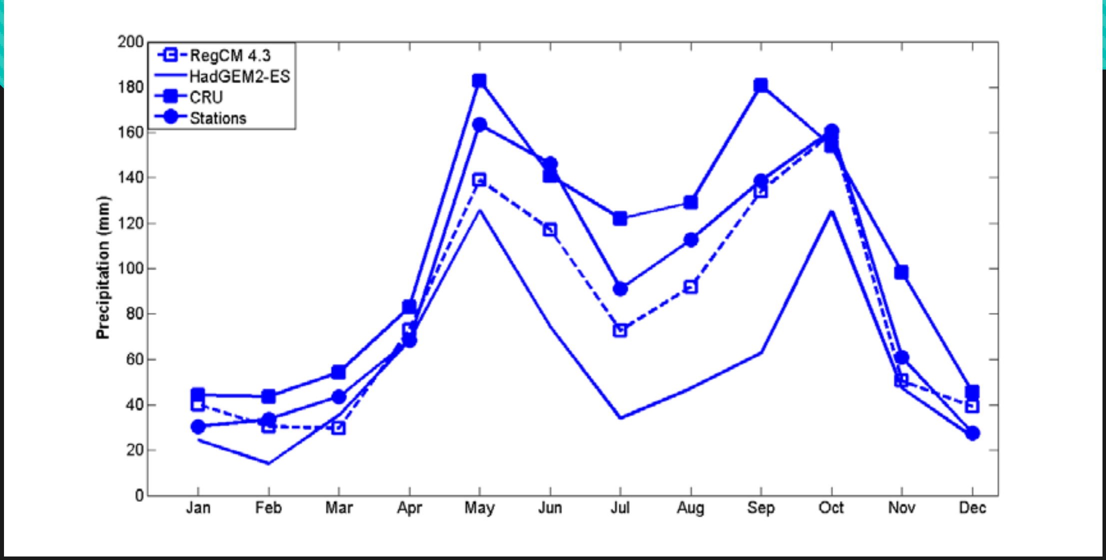


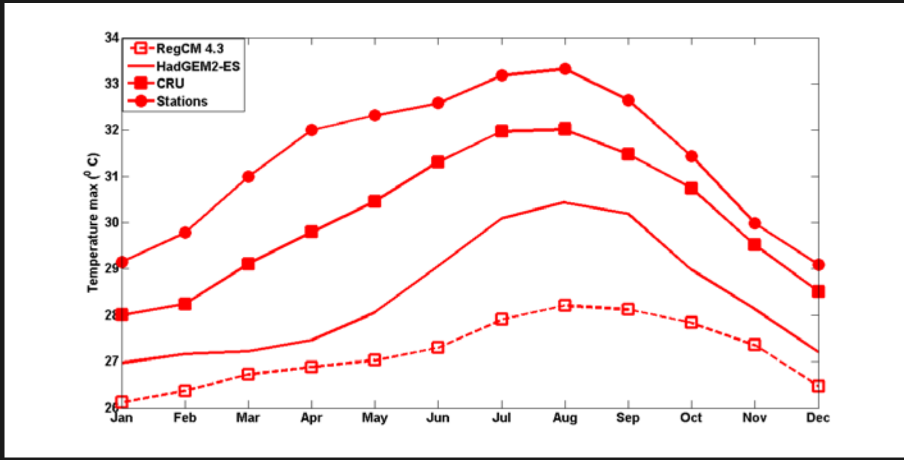
Las Coloradas Sub-basin

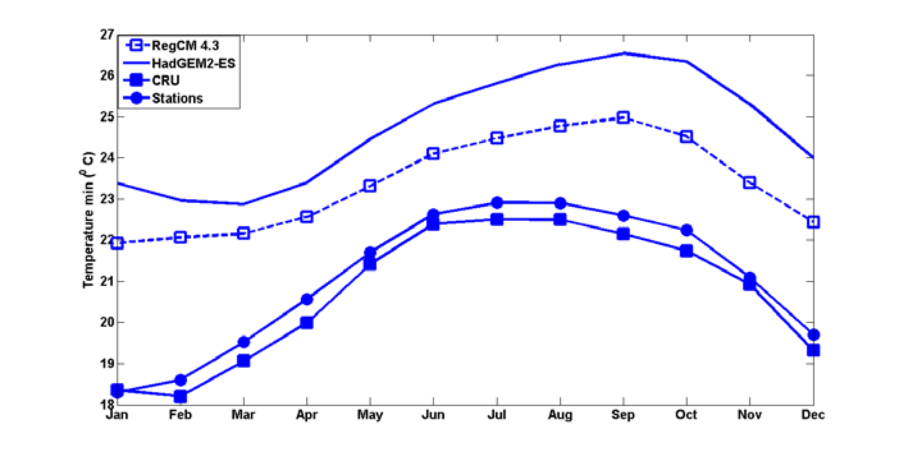


The results indicated ET dominates water yield

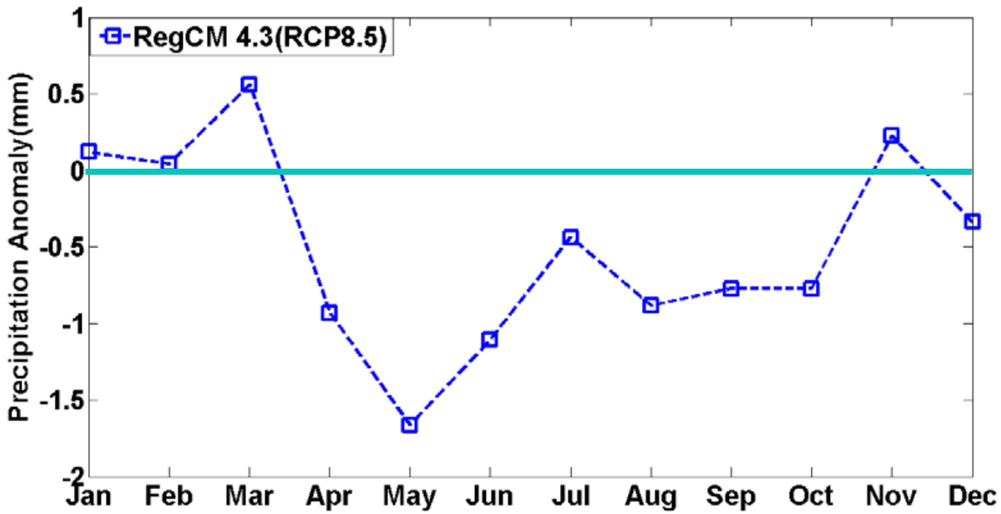
RegCM 4.3 Model Validation





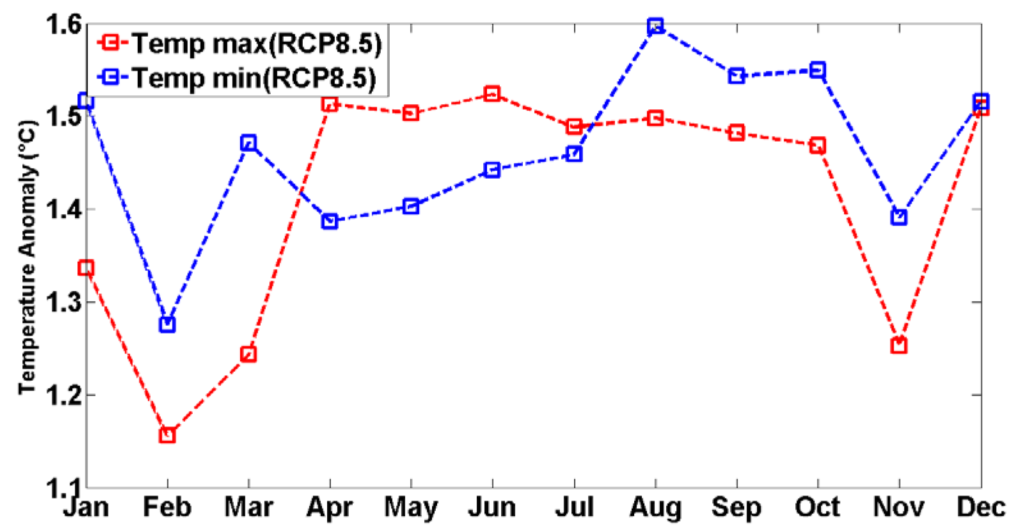


Climate Change Scenario



The future precipitation showed general tendency of decrease for summer, increase in winter

Temperature more than 1˚C in 2015-2039



Netx steps

- Based on the results SWAT model can be used for further analysis of the effect of climate and land use changes on hydrological processes.

- Present work should be considered as a first step in the development of a larger model in which a calibration is performed for multiple sites within the basin.

Conclusion

The SWAT model has been applied in two sub-basins the River Cauto basin and it showed a general good performance.

The parameters obtained show to have a good representation for the upper and middle region of the basin. We found that the U.S. Soil Conservation Service curve number (CN2) was the most sensitive parameter, while the soil evaporation compensation factor (ESCO) and available soil water capacity (SOL_AWC) were also important.

Previous to this investigation did not have data of adjusted parameters that allowed to simulate basins in conditions of this type in the country.

The annual change and season variation of hydrologic components due to future temperature increase and precipitation changes should be evaluate and incorporated into water resources planning and management in order to promote more sustainable water demand and water availability for a stream watershed of our country.

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Thanks for your attention!!!!