Development of reservoir operation functions in SWAT+ using a generic data-driven reservoir operation model

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CRBE CENTRE DE RECHERCHE SUR LA BIODIVERSITE ET L'ENVIRONNEMENT

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BECAS DON CARLOS ANTONIO LÓPEZ Excelencia es futuro

Water Supply
Flood control
Hydropower Generation
Navigation
Ecosystem protection
Recreation

Reservoirs

Streamflow can be modified by reservoir construction and operation

Represent the real-world reservoir operation behaviors

Better understand the impacts of reservoir on natural and human systems

SWAT+
SOIL & WATER ASSESSMENT TOOL

Modelling

Decision Tables: extract realistic reservoir operation rules

Decision tables are a great way to represent real world reservoir operations

Name	Conditions	Alternates	Actions							
res_release	5	5	5							
VAR	OBJ	OB_NUM	LIM_VAR	LIM_OP	LIM_CONST	ALT1	ALT2	ALT3	ALT4	ALT5
vol	res	0	pvol	*	0.8	<	>	-	>	-
vol	res	0	pvol	*	1.3	-	<	>	-	-
vol	res	0	evol	*	1	-	-	<	<	>
month	null	0	null	-	5	-	>	>	<	-
month	null	0	null	-	9	-	<	<	>	-
ACT_TYP	OBJ	OB_NUM	NAME	TYPE	CONST	OUTCOME				
release	res	0	below_principal	days	150.	y	n	n	n	n
release	res	0	non-flood<1.3	days	100.	n	y	n	n	n
release	res	0	non-flood>1.3	days	50.	n	n	y	n	n
release	res	0	flood	days	25.	n	n	n	y	n
release	res	0	over_emergency	days	5.	n	n	n	n	y

SWAT+
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Depicting the decision rules can be challenging

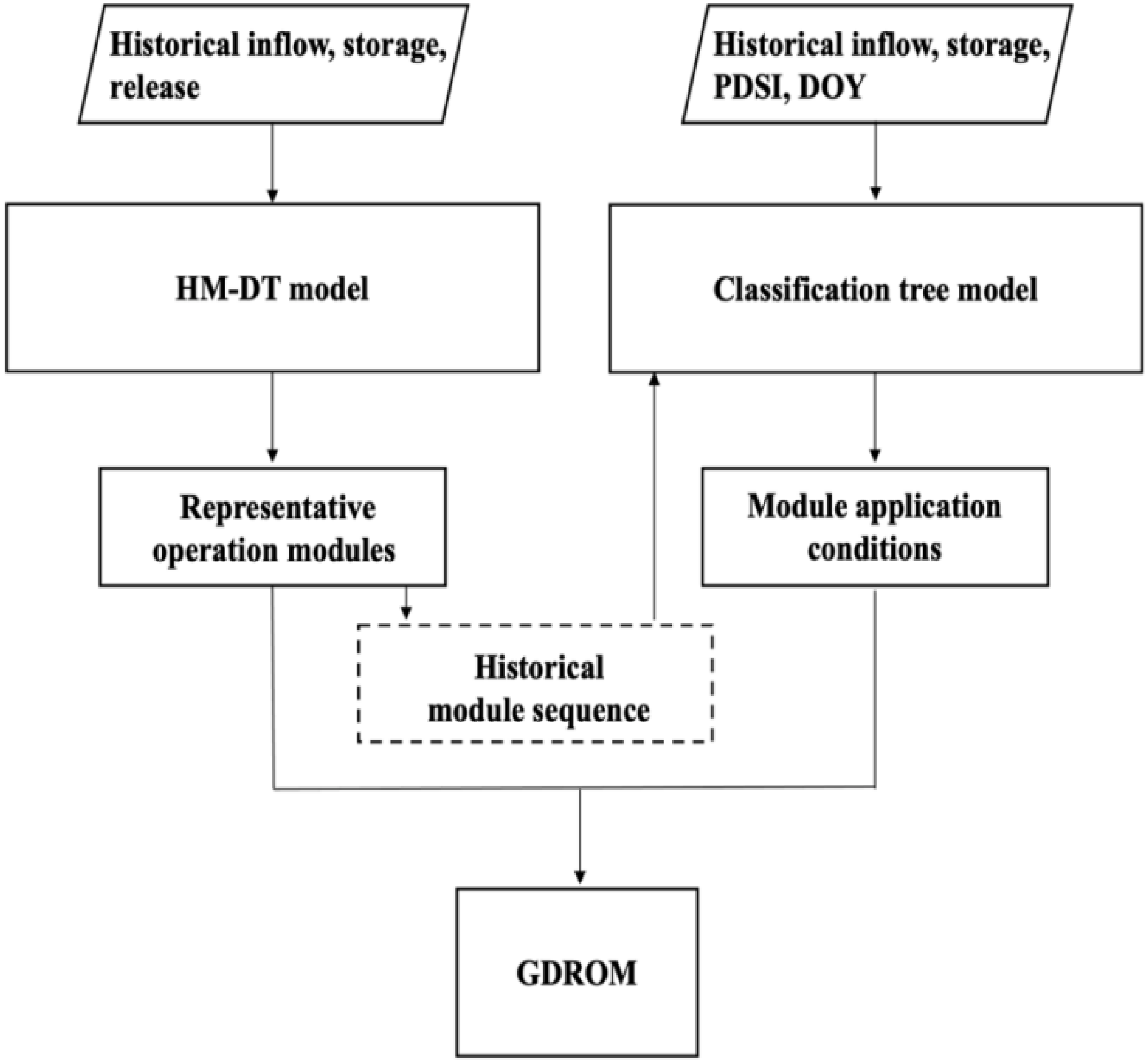
- Lack of operational data – I cannot reproduce the decision rules!
- Complexity of reservoir functions (production of energy, irrigation, flood control, ecological actions) thus time consuming.
- Hydrology of the basin is highly affected because of the presence of VARIOUS reservoirs.

Machine Learning can help

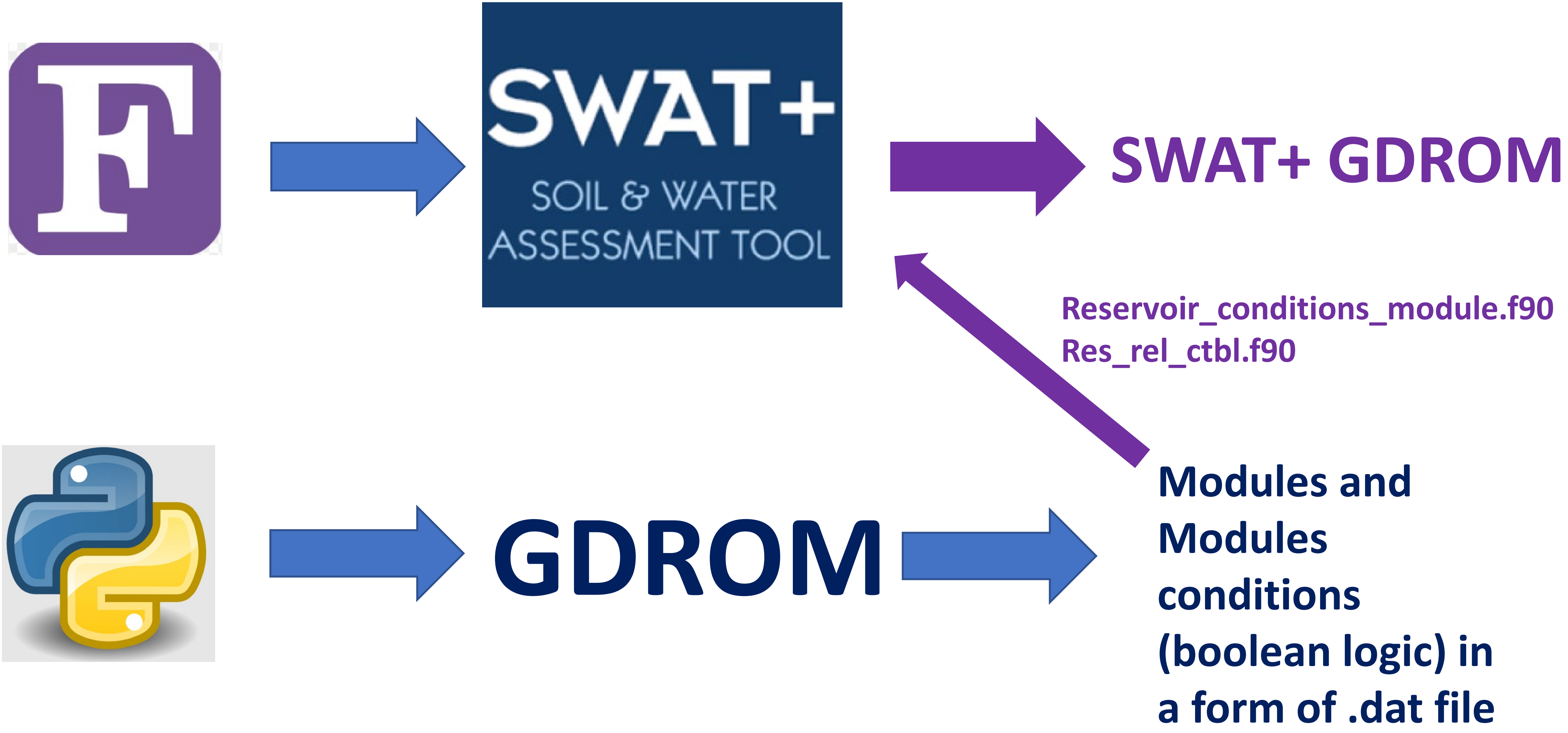
- In recent years, ML techniques including ANN, support vector machine and regression, and decision trees have been used to extract reservoir operation rules.
- Decision trees are simple and easy to interpret, because they follow a Boolean logic (‘true or false’) in the partitioning process which is similar to the decision-making real-world reservoir operation.
- GDROM: couples a HM-DT with a classification model that determines which module derived from the HM-DT to apply given a hydroclimatic condition.
- The GDROM is generic for reservoirs for various operations functions, capacities and locations.

The GDROM

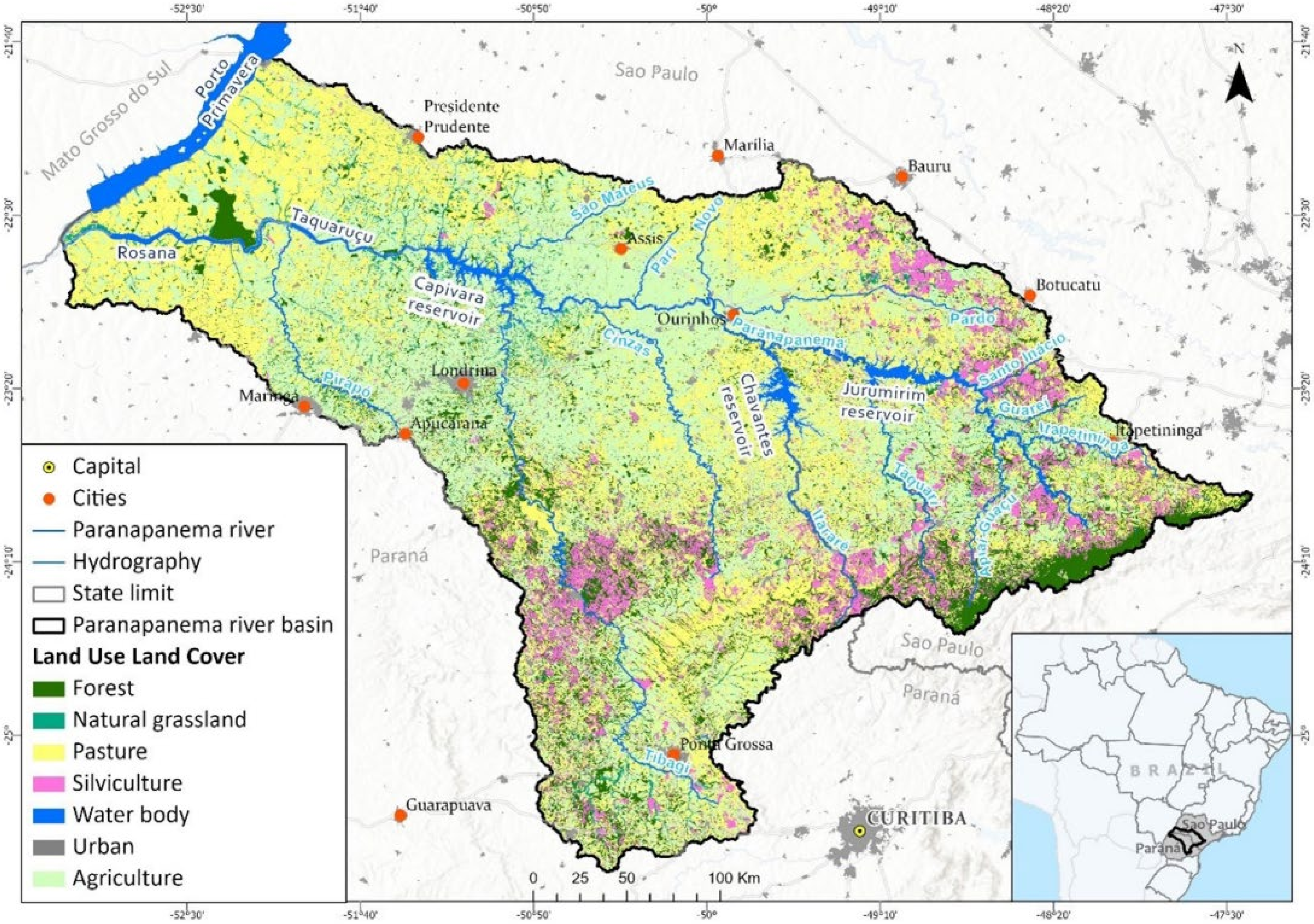
1. Combination between a Hidden Markov Decision Tree and a classification tree.
2. The GDROM combines the identified operation modules and the module application conditions to simulate reservoir releases
3. Input data: historical inflow, storage, release, DOY and PDSI (not used in this work).



SWAT+ GDROM


SWAT+
SOIL & WATER
ASSESSMENT TOOL
SWAT+ GDROM
Reservoir_conditions_module.f90
Res_rel_ctbl.f90
GDROM
Modules and
Modules
conditions
(boolean logic) in
a form of .dat file

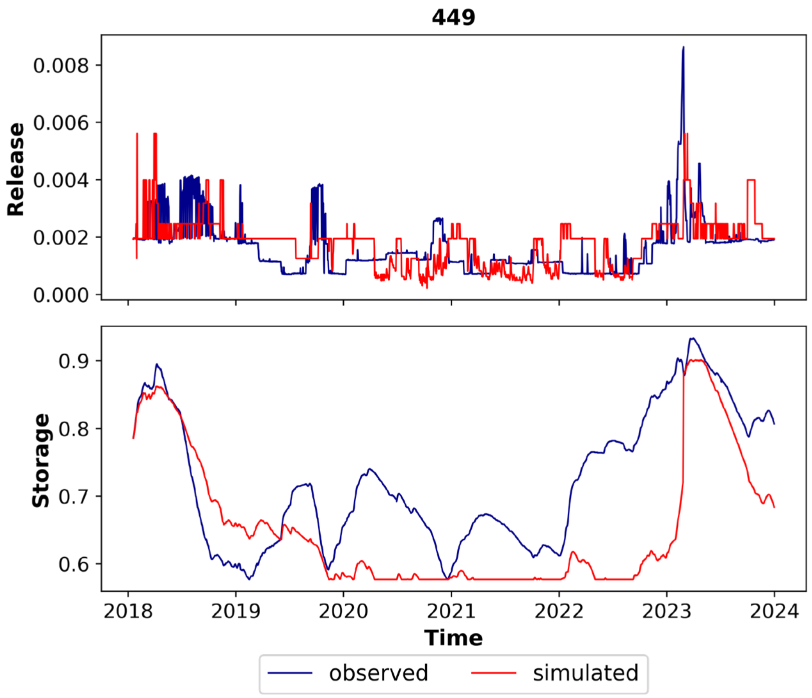
Case Study: Paranapanema river in the Upper Parana River Basin



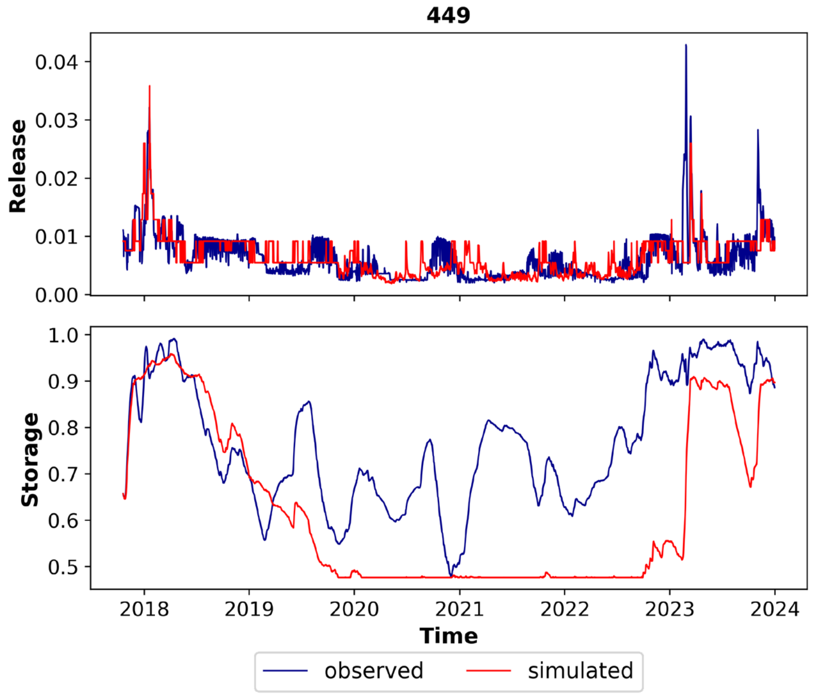
Study Area

1. Drainage Area: 100,800 km2
2. Annual avg PCP: 1400 mm
3. Climate: Subtropical
4. Four large multipurpose hydroelectric dams have been installed: Jurumirim, Chavantes, Capivara and Rosana

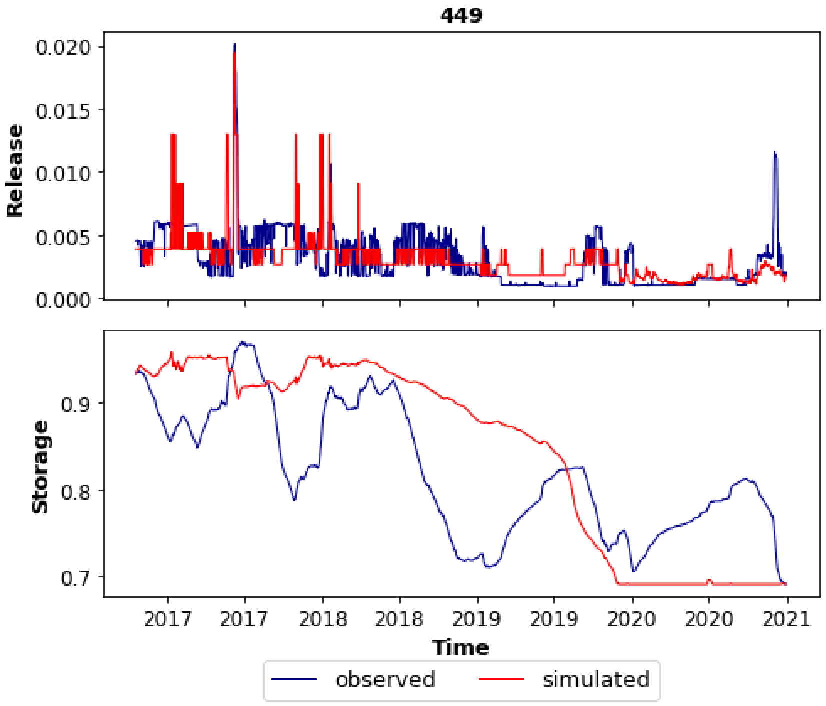
Taken from Acosta et al. 2023



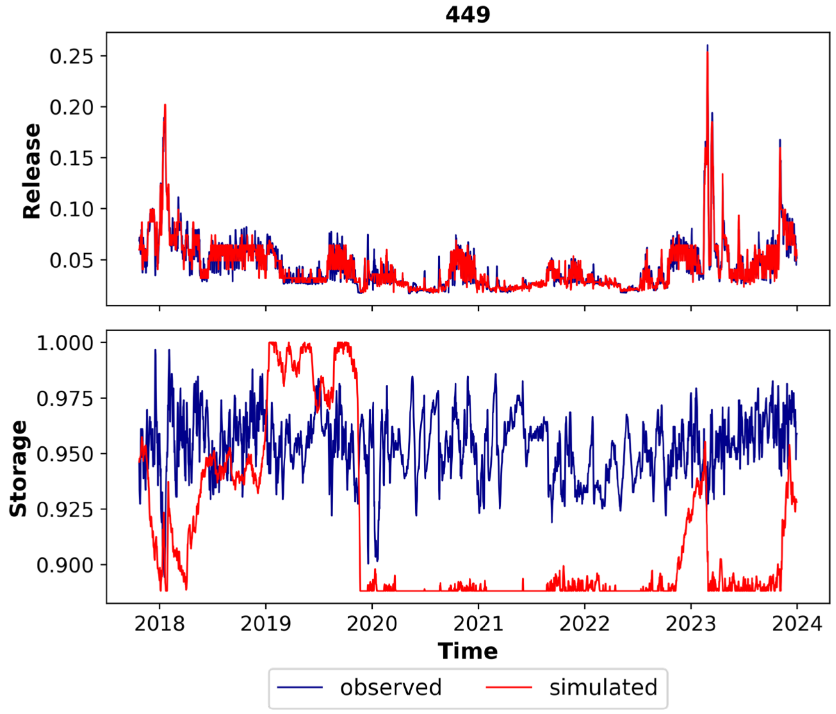
Jurumirim



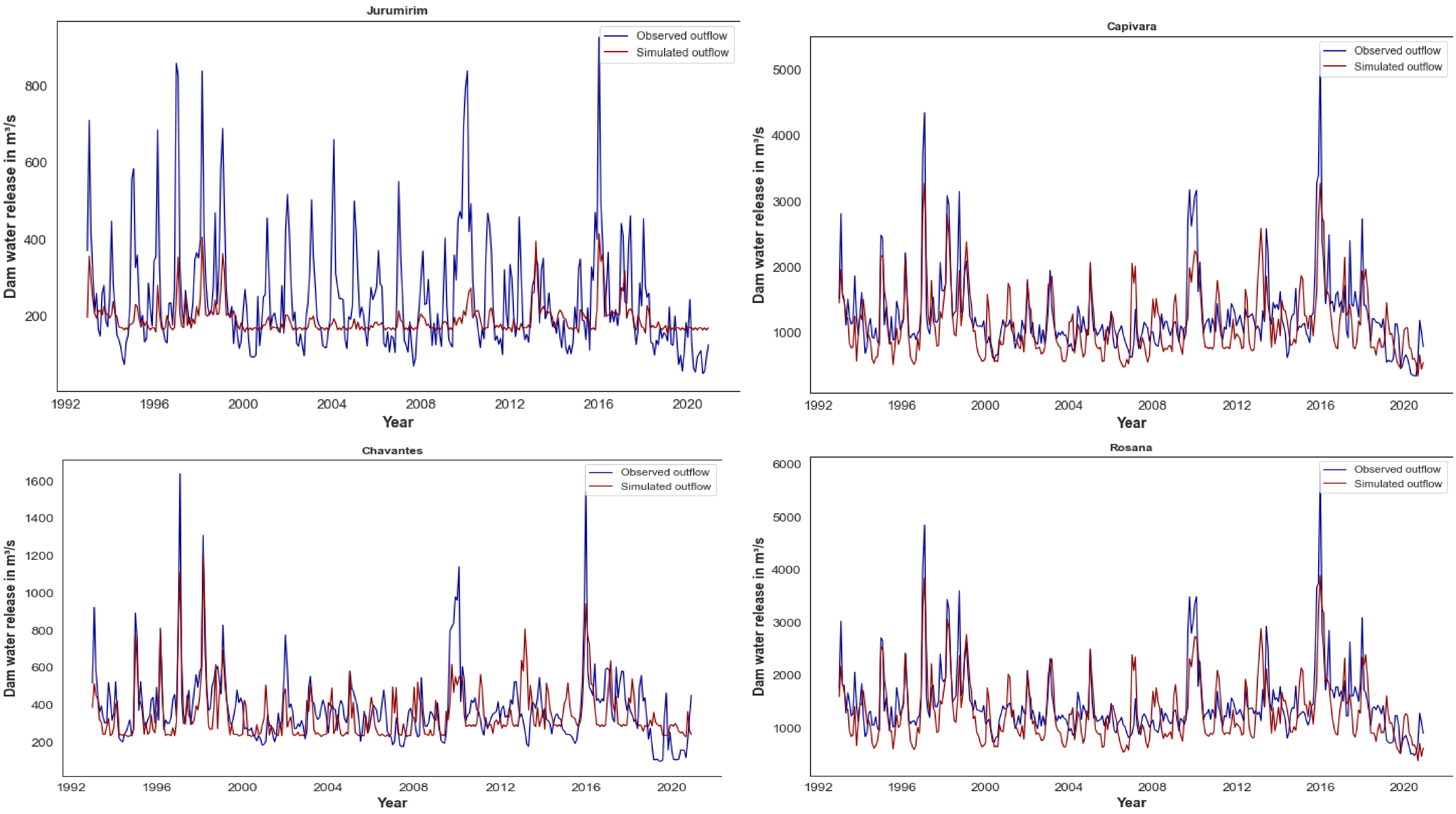
Capivara



Chavantes



Rosana


Jurumirim
Observed outflow
Simulated outflow
Dam water release in m³/s
Year
Capivara
Chavantes
Rosana
1992 1996 2000 2004 2008 2012 2016 2020
200 400 600 800
1000 2000 3000 4000 5000
200 400 600 800 1000 1200 1400 1600
1000 2000 3000 4000 5000 6000

Calibration Results

Reservoir	NSE	PBIAS	R2	KGE
Jurumirim	0.14	-22.22	0.38	0.15
Capivara	0.40	-15.41	0.53	0.64
Chavantes	0.35	-12.53	0.42	0.44
Rosana	0.37	-21.34	0.61	0.67

Conclusion

- A new ML method is available for depicting DT rules for reservoir release.
- New routines were added to SWAT+ that allows to use the decoded rules from the GDROM. New res_conds.dat file is necessary for reading the rules. The routines are present in the new SWAT+ release.
- The GDROM (or any reservoir models developed separately from a host hydrological model) can improve by adding additional variable, but if we want to go further with our results we must compromise with the host hydrological model by dropping variables that cannot be provided during simulations.
- The GDROM code is available in github: https://github.com/lidh966/GDROM

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Thank you! Merci! Gracias! ありがとう！

Questions?

```
res_conds.dat  paranapanema river
   16
ctbl_rosana  32    4
   5    inflo <= 113892479.9   inflo <= 83840830.2   stor <= 1918228245.0   day <= 137   day <= 41   1
   5    inflo <= 113892479.9   inflo <= 83840830.2   stor <= 1918228245.0   day <= 137   day > 41   0
   5    inflo <= 113892479.9   inflo <= 83840830.2   stor <= 1918228245.0   day > 137   day <= 319   2
   5    inflo <= 113892479.9   inflo <= 83840830.2   stor <= 1918228245.0   day > 137   day > 319   1
```

```
5   inflo <= 297487732.2   inflo <= 111481055.7   inflo <= 85784830.2   inflo <= 63920017.7   inflo <= 50068800.1   46008235.0
7   inflo <= 297487732.2   inflo <= 111481055.7   inflo <= 85784830.2   inflo <= 63920017.7   inflo > 50068800.1   stor <= 1952729049.8   stor <= 1898979076.9   66359391.5
8   inflo <= 297487732.2   inflo <= 111481055.7   inflo <= 85784830.2   inflo <= 63920017.7   inflo > 50068800.1   stor <= 1952729049.8   stor > 1898979076.9   inflo <= 61549200.1   56360307.0
```