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Overcoming challenges of large-scale SWAT applications with R: Modelling of the Amazon basin

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International SWAT Conference in Warsaw, 30.06.2017

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Input data

- Land use: USGS landuse / land cover (1 km)
- Soil type: UN FAO (9 km; FAO, 2003)
- Topography: DEM SRTM 90 m
- Weather data: WATCH Forcing Data applied to ERA-Interim (WFDEI; Weedon et al., 2014)

Dimensions of the model

- Subbasins: 3,221
- HRUs: 9,476
- Period: 1983–2010
- Simulation running time: >70 min

Calibration strategy

Hierarchical calibration

- Start calibration with headwaters (independent channels)
- Calibrate gauges (SWAT-CUP)
- Substitute calibrated parameters (best_par.txt)
  - All subbasins that deliver to the point of calibration
- Move downstream for next calibration round
- Used before (Monteiro et al., 2016*b*,*a*)

Recording best_par.txt

par_inf.txt

224 : Number of Parameters
500 : number of simulations

r__CN2.mgt_____205,211,. . . ,454	0.1	0.35
v__ESCO.hru_____205,211,. . . ,454	0.8	1
. . .		
r__CN2.mgt_____530,531,. . . ,671	-0.3	-0.1
v__ESCO.hru_____530,531,. . . ,671	0.4	0.7
. . .		

best_par.txt

Goal_type= bR2 No_sims= 500 Best_sim_no= 54 Best_goal = 7.062255e-001

Parameter_Name	Fitted_Value	Min_value	Max_value
1:R__CN2.mgt	0.118750	0.100000	0.350000
2:V__ESCO.hru	0.908200	0.800000	1.000000
. . .			

Recording best_par.txt

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v__ESCO.hru_____530,531,...,671	0.4	0.7
...		

Observed.txt - weighing gauges

13 : number of observed variables
6 : Objective function type
0.3 : min value of objective function

BR_Q_454 : this is the name of the variable
1 : weight of the variable in the objective function
...
BR_Q_671 : this is the name of the variable
0 : weight of the variable in the objective function
...

best_par.txt

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...			

Challenge

- Extract and save for one gauge at a time
- Link fitted parameters to subbasins

Recording best_par.txt

matrix:

	[,1]	[,2]
[1,]	1	17
[2,]	18	34
...	...	...
[13,]	208	224

Matrix

- Lines: Gauges
- Columns:
  - [,1] first parameter
  - [,2] last parameter

```
1 read.table('C:/.../gauges.txt', header=T, sep='\t')->gauges
```

gauges:

Name	Lat	Long	Subbasin	Round	Nested
16480000	-0.689	-57.970	454	1	205,211,...,454
18200000	-1.779	-54.400	671	1	530,531,671
...					

Recording best_par.txt

```
2  #Before starting, execute SUFI2_pre.bat and SUFI2_run.bat. Set weight
     = 1 (Observed.txt) to the first gauge, elsewhere weight = 0, then
   run SUFI_post.bat
3  bestpar<-{} #Create an empty object to hold sorted values from
   best_par
4  i=1 #Start with the first gauge
5
6  read.table('C:/.../best_par.txt', skip=3, fill=T)->df #Read best_par
   from simulation
7  data.frame(gauge=c(gauges[i,4], rep('', dim(df[c(parse.parameters[i
   ,1]:parse.parameters[i,2]),])[1]-1)), df[c(parse.parameters[i,1]:
   parse.parameters[i,2]),])->df
8  rbind(bestpar, df)->bestpar #Data frame 4 columns: gauge number and
   respective lines from best_par
9  i+1->i # Move to the next gauge by changing the weight accordingly (
   Observed.txt). Run SUFI_post.bat to extract for it and start the
   code from line 6
10
11 names(bestpar)[2:5]<-c('Par', 'Fitted', 'Min', 'Max') #Set meaningful
     names
12 write.table(bestpar, 'C:/.../bestpar_round01.txt', sep='\t', row.
   names=F, quote=F) #Save the results
```

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Description of the procedure

1. Execute SUFI2_pre.bat, and SUFI2_run.bat
2. Adjust weights in (Observed.txt)
3. Execute SUFI_post.bat
4. Create container for sorted fitted parameters (here, ‘bestpar’)
5. Set index to point to which gauge will be extracted for
6. Read best_par.txt
7. Save in the auxiliary file the gauge name and parameters
8. Pull auxiliary file to container
9. Set index to next gauge
10. Adjust weights for next extraction
11. Repeat from item 3 (until last gauge)
12. Save results (container object)

Substituting calibrated parameters

- Important: Back up original tables in mdb file! e.g.: gw (gw_orig)

Add gauge name to matrix of numbers of parameters

```
13 data.frame(gauges[,4], parse.parameters)->num.par
14 names(num.par)<-c('gauge', 'par begin', 'par end')
```

Parse information of best_par for use: e.g.:1:R__CN2.mgt

Type of change	Parameter	Table
R	CN2	mgt

```
15 require(reshape2)
16 colsplit(bestpar[,2], pattern=':', names=c('a', 'b'))->aux01
17 substr(aux01[,2], 1,1)->type_change
18 substr(aux01[,2], 4, nchar(aux01[,2]))->aux02
19 data.frame(matrix(unlist(lapply(as.character(aux02), function(x){a<-
     unlist(strsplit(x, split="[().]"))
20 a<-a[nchar(a)>0]})), ncol = 2, byrow=T))->aux03
21 names(aux03)=c('par', 'table')
22 data.frame(type_change, aux03, fitted=round(bestpar[,3], digits=4),
     gauge=rep(NA), nested=rep(NA))->ChangeParam
23 vec<-{}
```

Substituting calibrated parameters

```
24 for (i in 1:dim(num.par)[1]){
25   rep(num.par[i,1], each=num.par[i,3]-num.par[i,2], after=length(vec)
       )->vec2
26   append(vec, vec2)->vec
27 }
28 ChangeParam[,5]<-vec
29 for(i in 1:dim(ChangeParam)[1]){
30   ChangeParam[i,6]<-as.character(gauges[gauges$subbasin==ChangeParam[
       i,5],6])
31 }
```

ChangeParam: Information to execute parameter substitution in mdb file

type_change	par	table	fitted	gauge	nested
R	CN2	mgt	0.1188	454	205,211,...,454
V	ESCO	hru	0.9082	454	205,211,...,454
...					

Substituting calibrated parameters

```
require(ImportExport) #To connect to database (.mdb)
used.tables<-c('mgt1', 'hru', 'gw', 'rte', 'sub', 'sol') #Vector with names of tables to use
for (w in used.tables) {
  assign(w, access_import("C:/.../Amazonian.mdb", w)) #Import tables
}
levels(ChangeParam$table)[3] <- "mgt1" #Name of table in mdb is different from SWAT_CUP

for (i in 1:dim(ChangeParam)[1]){
  TABLE<-get(as.character(ChangeParam[i,'table']))
  PAR<-as.character(ChangeParam[i,'par'])
  TYPE<-as.character(ChangeParam[i,'type_change'])
  NESTED<-as.numeric(unlist(strsplit(ChangeParam[i,'nested'], split=',')))

if(ChangeParam[i,1]=='R') TABLE[TABLE$SUBBASIN %in% NESTED, colnames(TABLE)==PAR] <- TABLE[
   TABLE$SUBBASIN %in% NESTED, colnames(TABLE)==PAR] * (1 + ChangeParam[i,4])
if(ChangeParam[i,1]=='V') TABLE[TABLE$SUBBASIN %in% NESTED, colnames(TABLE)==PAR] <-
   ChangeParam[i,4]
if(ChangeParam[i,1]=='A') TABLE[TABLE$SUBBASIN %in% NESTED, colnames(TABLE)==PAR] <- TABLE[
   TABLE$SUBBASIN %in% NESTED, colnames(TABLE)==PAR] + ChangeParam[i,4]

assign(as.character(ChangeParam[i,3]), TABLE)

}

for (w in used.tables) {
  access_export("C:/.../Amazon.mdb", get(w), paste(w, "round01", sep = "_"))
}
```

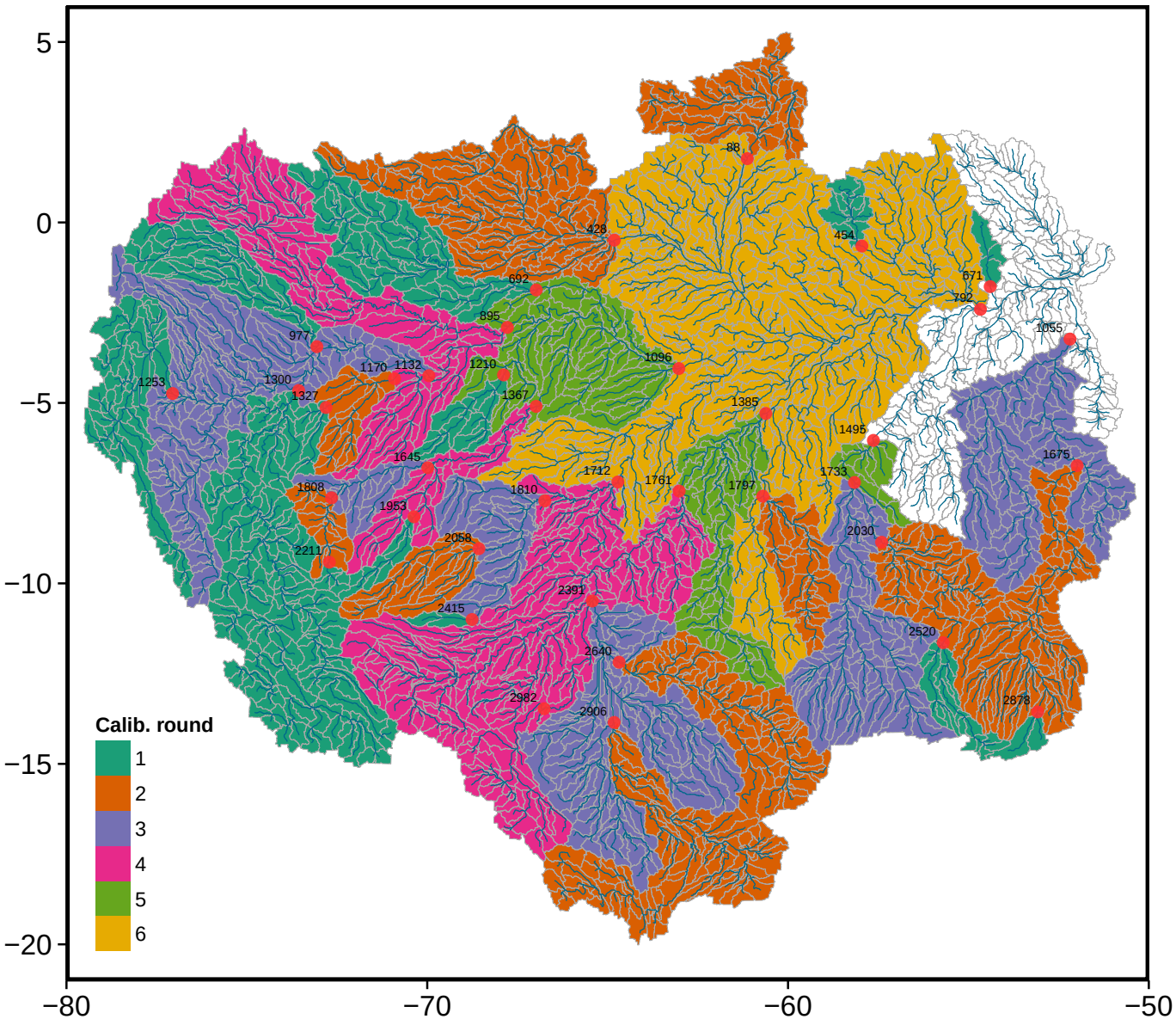
Last adjustments in file .mdb

Amazon.mdb

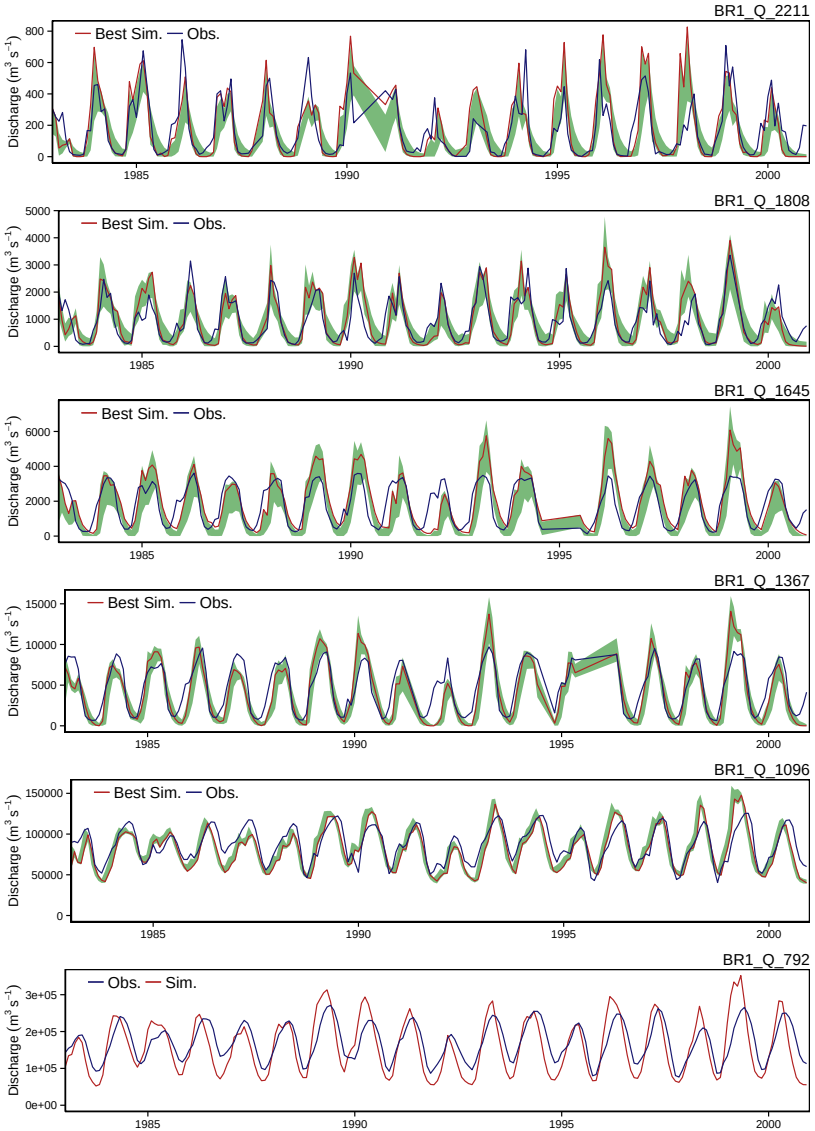
gw	gw_orig	gw_round01
hru	hru_orig	hru_round01
mgt1	mgt1_orig	mgt1_round01
. . .		

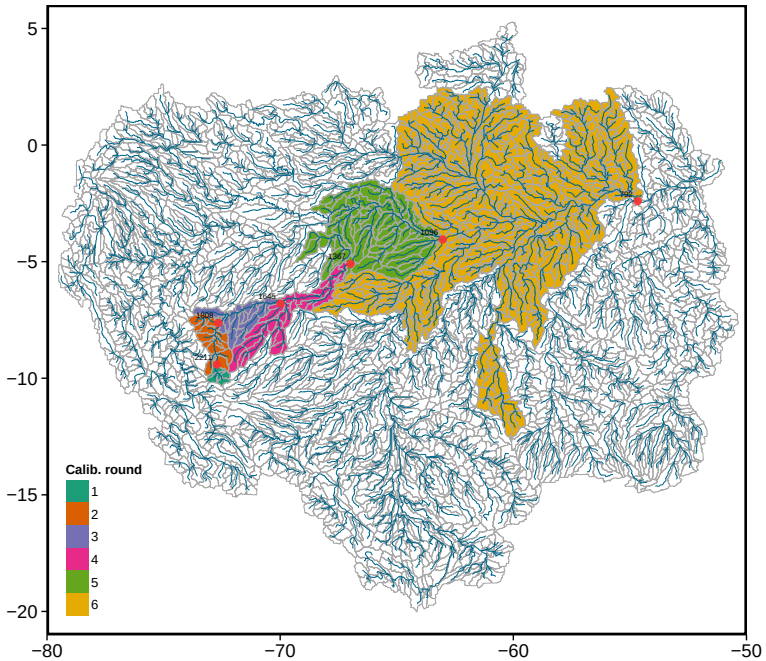
1. Remove colum “rownames” in _round01 files
2. Make a copy of each _round01 file and rename to the original name (e.g. “Copy Of gw_round01” to “gw”)
3. Rewrite respective tables in SWAT

Hierarchical calibration in the Amazon



Hydrographs





Gauge	p-factor	r-factor	R^2	bR^2	NS	Pbias
Q_2211	0.6	0.79	0.57	0.56	0.37	7.3
Q_1808	0.71	1.07	0.69	0.66	0.53	5.1
Q_1645	0.5	1.08	0.64	0.59	0.41	10.2
Q_1367	0.54	0.85	0.75	0.7	0.62	−10.3
Q_1096	0.3	0.68	0.74	0.69	0.56	−6.9
Q_792			0.66	0.63	0.16	−6.6

Thank you for your time!

Questions?

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