# Running an assimilation experiment with SECHIBA – YAO

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## Introduction

ORCHIDEE is a model representing the continental biosphere and its different processes, comprising the simulation of soil and vegetation mechanism and simulating different fluxes between the soil-atmosphere interface (Polcher et al., 1998, Krinner et al., 2005, Brender, 2012). ORCHIDEE has different time scales: energy and matter has a 30-minutes time scale. Species competition processes at 1-year time scale. The vegetation is grouped into 13 Plant Functional Type (PFT). The equations governing the processes are general, with specific parameters for each PFT. ORCHIDEE is used in a grid-point mode (one given location), forced with the corresponding local half hourly gap-filled meteorological measurements.

SECHIBA (Schématisation des Echanges Hydriques à l'Interface Biosphère-Atmosphère) (Ducoudré et al, 1993) is a biophysical model. It calculates the radiation and energy budgets of the surface, and the soil water budget every half hour. The energy and water fluxes between the atmosphere and the ground integrate all the vegetation layers; the retrieved temperature represents the canopy ensemble and the soil surface. The main fluxes modeled are the sensible and latent heat flux between the atmosphere and biosphere, the soil temperature and the water reservoirs evolution, the stomata conductance and gross primary productivity of the canopy.

The distributed version of SECHIBA-YAO provides an opportunity for scientists to perform their own assimilation. The users can perform 4DVAR assimilation in a point with their own forcing file. SECHIBA-YAO allows the control of the five most influential internal parameters of SECHIBA (with respect to the vegetation type). Land surface temperature can be used as observations.

The parameters considered in the twin experiments are taken from the sensitivity analysis results presented in Benavides (2014). Each experiment was perturbed with a uniform distribution random noise reaching 50% of the parameter nominal value

In Experiment 1 the five most sensitive parameters are controlled in bare soil conditions, during one week in Harvard Forest sites.

In Experiment 2 the five most sensitive parameters are controlled in conditions of agricuktural C3 (PFT 12) in Harvard Forest site during a week.

For both experiments, an instruction file is given. This file (extension .i) is necessary in order to run an experiment through SECHIBA -YAO. It includes the initialization of the inner parameters and model variables, parameters perturbed values prior to assimilation and the presentation of the final results after the assimilation process.

In the next sections, the structure of the instruction file is presented for the experiment 1, pointing out the parts that can be modifiable by the user and the different key words needed to run an assimilation experiment

# 1. Installing and using SECHIBA – YAO

SECHIBA – YAO must be installer in a linux-based operational system. In order to installed it, you have to deploy the compressed file in your local environment and run the makefile to generate the executable.

There are several folders in SECHIBA-YAO distribution

* the *example* folder contains everything you need to run experiments 1 and 2: forcing files, inputs, instruction files and outputs
* the *doc* folder contains the instruction manual and some other interesting documents
* The other folders contain the files needed to compile and run SECHIBA-YAO

In order to deploy SECHIBA-YAO in your local environment, several variables in the makefile has to be modified, if needed:

* LIBNC and INCNC make reference to netcdf libraries needed to read fircing files
* LDFLAGS is a variable containing flags to several refereences needed to compile
* CXX contains the compiler, it can be changed if needed

Once the installation process is done, the software need an instruction file in order to run the different experiences. There are two instruction files provided with this release, corresponding to experiment 1 and 2, mentioned in the introduction. In the next part, the structure of the instruction file is explained.

Running SECHIBA -YAO is done by using this command:

*./bin/sechiba -i ./examples/assim\_HV\_PFT12.i*

where *./examples/assim\_HV\_PFT1.i* is the location of the instruction file

# 2. Instruction file

## Mandatory functions

###########################################

# 0) MANDATORY FUNCTIONS

###########################################

################################ PDF Inizialization #############################

xPFT 1 0 0 0 0 0 0 0 0 0 0 0 0

######## Select the day of the beginning of the experiment (in step time) ######

xbypass\_jour 3216

############################### Forcing file ###################################

xinit\_forcing ./examples/forcing/ 1996US-Ha1.nc

######### Initial values of the model parameters (don't modify) ################

#---------- rsol socapa\_wet socapa\_dry min\_drain max\_drain exp\_drain so\_capa so\_cond dpu\_cste mx\_eau\_eau rveg z0\_p z0\_over\_height albvis albnir emissitive

xparam\_init 33000 3.03e+06 1.80e+6 0.001 0.2 1.5 1 1 2 150 1 1 0.046 1 1 0.96

############# Initials humcste values, one for each PFT (don't modify)###########

#------------ h1 h2 h3 h4 h5 h6 h7 h8 h9 h10 h11 h12 h13

xparam\_humrel 5 0.8 0.8 1 0.8 0.8 1 1 0.8 4 4 4 4

Figure 1. Mandatory functions

The first section is a function section (0) containing a number of mandatory functions needed to run SECHIBA-YAO.

* **Xbypass\_jour** allows to start the assimilation in a determined date of the year. It is obtained by multiplying the day number of the year by the step time in a single day (48). For example the day 3216 correspond to the 07-03
* **Xparam\_init** allows to initialize the different parameters. They cannot be modified by the user. These are SECHIBA inner parameter values.
* **Xparam\_humrel** initialize moisture processes parameters. This cannot be changed.
* Finally the function **xinit\_forcing** contains the path to the forcing file. If forcing files are longer than a year, they must be separated in a file per year, SECHIBA-YAO will automatically append each year. The format of the files must be netcdf with a specific structure that can be detailed in the examples files given in the distributed version
* The function **xPFT** serves to initialize the PFT according to the Plant Functional Type wished for the experiment. A number between 0 and 1 represent the percentage of each type of vegetation. Several vegetation type can be configured at the same time. For example if we have for a given point bare soil (PFT 1) and agricultural C3 (PFT 12), the function must be configured as follows: *xPFT 0.3 0 0 0 0 0 0 0 0 0 0 0.7 0*. Each number correspond to the percentage of PFT in the point of study. For more information on PFT description, consult d'Orgeval (2006) or Benavides (2014)

## Model initialization

################################################################################

########################## 1) MODEL INITIALIZATION ##########################

###############################################################################

################## Variables initial Conditions #############################

setstate temp\_sol 273

setstate netrad 0

setstate fluxsens 0

setstate fluxlat 0

setstate evapnu 0

setstate transpir 0

setstate ptn 273

setstate qsintveg 0

######################### Hydrological variables ###############################

setstate h\_c\_1 1

setstate h\_c\_2 0

setstate h\_c\_3 0

setstate h\_c\_4 0

setstate h\_c\_5 0

setstate h\_c\_6 0

setstate h\_c\_7 0

setstate h\_c\_8 0

setstate h\_c\_9 0

setstate h\_c\_10 0

setstate h\_c\_11 0

setstate h\_c\_12 0

setstate h\_c\_13 0

setstate bqsb\_init 300

setstate gqsb\_init 0.001

Figure 2. Model state initialization

In this section, two different parts are defined: The model state initialization and the parameter initialization. In figure 2, an example of model state initialization is presented. Each line corresponds to the initialization of a model variable. In particular, the h\_c\_ variables correspond to the initial value of the soil water stress by PFT. This value is between 0 and 1.

################# Initialization of controllable parameters #####################

setstate rsol\_c 1

setstate min\_drain\_c 1

setstate rveg\_c 1

setstate z0\_c 1

setstate emis\_c 1

setstate so\_capa\_c 1

setstate so\_cond\_c 1

setstate mx\_eau\_c 1

setstate dpu\_c 1

setstate albvis\_c 1

setstate hum\_c\_12 1

setstate hum\_c\_1 1

setstate hum\_c\_2 1

setstate hum\_c\_3 1

setstate hum\_c\_4 1

setstate hum\_c\_5 1

setstate hum\_c\_6 1

setstate hum\_c\_7 1

setstate hum\_c\_8 1

setstate hum\_c\_9 1

setstate hum\_c\_10 1

setstate hum\_c\_11 1

setstate hum\_c\_13 1

setstate bqsb\_c 1

setstate gqsb\_c 1

setstate so\_dry\_c 1

setstate so\_wet\_c 1

setstate mx\_drain\_c 1

setstate e\_drain\_c 1

setstate z0\_over\_c 1

setstate albnir\_c 1

setstate eaumax 208.46

setstate eaumin 175.6886

setstate hummax 0.24431

setstate hummin 0.14463

Figure 3. Model parameter initialized

Afterwards, the model inner parameters must be initialized (Figure 3). Their value by default must be 1, in order to take the value defined in the mandatory section. If a value between 0 and 1 is taken, the parameter value is then multiply by the value defined in this section. In this experiment only 5 parameters are controlled: *so\_cond\_c, so\_capa\_c, z0\_c, emis\_c and albvis\_c.*

## Forward run

In this section the direct model is computed once in order to have the model state in the time framework chosen for the experiment and to produce the synthetic observations needed to run the twin experiment.

###############################################################################

################################# 2) FORWARD ################################

###############################################################################

set\_modeltime 0

FORWARD

set\_modeltime 0

############ Saving variables and parameters after execution of the direct model ##########

savestate E\_tempsol 1 i 0 A 3 ./examples/output/experience\_jumelle/HV\_PFT1/fluxes/E\_tempsol\_obs\_HV.dat

savestate E\_tempsol 1 i 0 A 3 ./examples/output/experience\_jumelle/HV\_PFT1/fluxes/E\_tempsol\_obs2\_HV.dat

savestate E\_fluxsens 1 i 0 A 3 ./examples/output/experience\_jumelle/HV\_PFT1/fluxes/E\_fluxsens\_obs\_HV.dat

savestate E\_fluxlat 1 i 0 A 3 ./examples/output/experience\_jumelle/HV\_PFT1/fluxes/E\_fluxlat\_obs\_HV.dat

savestate H\_soil\_humrel1 1 i 0 A 3 ./examples/output/experience\_jumelle/HV\_PFT1/fluxes/E\_humrel\_obs\_HV.dat

savestate T\_coef\_diff 2 i 0 A 3 ./examples/output/experience\_jumelle/HV\_PFT1/fluxes/T\_soilflx\_obs\_HV.dat

savestate E\_netrad 1 i 0 A 3 ./examples/output/experience\_jumelle/HV\_PFT1/fluxes/E\_netrad\_obs\_HV.dat

savestate H\_soil\_mean 1 ij 0 A 3 ./examples/output/experience\_jumelle/HV\_PFT1/fluxes/H\_bqsb\_obs\_HV.dat

savestate H\_soil\_mean 2 ij 0 A 3 ./examples/output/experience\_jumelle/HV\_PFT1/fluxes/H\_gqsb\_obs\_HV.dat

savestate z0\_c 1 i 0 A 1 ./examples/output/experience\_jumelle/HV\_PFT1/param/z0\_opt\_HV.dat

savestate so\_cond\_c 1 i 0 A 1 ./examples/output/experience\_jumelle/HV\_PFT1/param/so\_cond\_opt\_HV.dat

savestate so\_capa\_c 1 i 0 A 1 ./examples/output/experience\_jumelle/HV\_PFT1/param/so\_capa\_opt\_HV.dat

savestate emis\_c 1 i 0 A 1 ./examples/output/experience\_jumelle/HV\_PFT1/param/emis\_opt\_HV.dat

savestate albvis\_c 1 i 0 A 1 ./examples/output/experience\_jumelle/HV\_PFT1/param/albvis\_opt\_HV.dat

############### Load Observations for the twin experiments #################

LOADOBS E\_tempsol 1 i 0 A 1 ./examples/output/experience\_jumelle/HV\_PFT1/fluxes/E\_tempsol\_obs\_HV.dat D

Figure 4. Direct model computing

Regarding the forward procedure, several keywords are needed

* Before computing the direct model, time frame is initialized (*set\_modeltime 0*). Afterwards the forward is launch with the key work FORWARD
* Model sate is saved afterwards, in particular the land surface temperature modeled in the time frame. The command *savestate* allows us to perform this task.
* Finally , in this section the observations are loaded and they are available for the assimilation process (*LOADOBS* command)

In order to take a value to initialize the variable, the function format has to be respected

* Starting with **loadstate** sentence, followed by the variable name
* Next the different digits concerning inner parameter of the loadstate function must be preserved (**1 i 0 A 1**)
* User can only modify the path to their initial value (in a text file always in YAO format)

## Minimization

###############################################################################

############## 3) MINIMIZATION M1QN3 (without constrains) ####################

###############################################################################

############## Adding random noise to control parameters ##################

setstate z0\_c 0.7182

setstate so\_capa\_c 0.5501

setstate so\_cond\_c 0.5102

setstate emis\_c 0.8531

setstate albvis\_c 0.6175

################### Before Optimization (first guess) #####################

set\_modeltime 0

FORWARD

set\_modeltime 0

################################# Saving First Guess #######################

savestate z0\_c 1 i 0 A 1 ./examples/output/experience\_jumelle/HV\_PFT1/param/z0\_init\_HV.dat

savestate so\_cond\_c 1 i 0 A 1 ./examples/output/experience\_jumelle/HV\_PFT1/param/so\_cond\_init\_HV.dat

savestate so\_capa\_c 1 i 0 A 1 ./examples/output/experience\_jumelle/HV\_PFT1/param/so\_capa\_init\_HV.dat

savestate emis\_c 1 i 0 A 1 ./examples/output/experience\_jumelle/HV\_PFT1/param/emis\_init\_HV.dat

savestate albvis\_c 1 i 0 A 1 ./examples/output/experience\_jumelle/HV\_PFT1/param/albvis\_init\_HV.dat

savestate rsol\_c 1 i 0 A 1 ./examples/output/experience\_jumelle/HV\_PFT1/param/rsol\_c\_init\_HV.dat

savestate so\_capa\_c 1 i 0 A 1 ./examples/output/experience\_jumelle/HV\_PFT1/param/so\_capa\_init\_HV.dat

savestate so\_cond\_c 1 i 0 A 1 ./examples/output/experience\_jumelle/HV\_PFT1/param/so\_cond\_init\_HV.dat

savestate mx\_eau\_c 1 i 0 A 1 ./examples/output/experience\_jumelle/HV\_PFT1/param/mx\_eau\_init\_HV.dat

savestate dpu\_c 1 i 0 A 1 ./examples/output/experience\_jumelle/HV\_PFT1/param/dpu\_init\_HV.dat

savestate hum\_c\_12 1 i 0 A 1 ./examples/output/experience\_jumelle/HV\_PFT1/param/hum\_init\_HV.dat

savestate E\_tempsol 1 i 0 A 3 ./examples/output/experience\_jumelle/HV\_PFT1/fluxes/E\_tempsol\_init\_HV.dat

savestate E\_fluxsens 1 i 0 A 3 ./examples/output/experience\_jumelle/HV\_PFT1/fluxes/E\_fluxsens\_init\_HV.dat

savestate E\_fluxlat 1 i 0 A 3 ./examples/output/experience\_jumelle/HV\_PFT1/fluxes/E\_fluxlat\_init\_HV.dat

savestate H\_soil\_humrel1 1 i 0 A 3 ./examples/output/experience\_jumelle/HV\_PFT1/fluxes/E\_humrel\_init\_HV.dat

savestate T\_coef\_diff 2 i 0 A 3 ./examples/output/experience\_jumelle/HV\_PFT1/fluxes/T\_soilflx\_init\_HV.dat

savestate E\_netrad 1 i 0 A 3 ./examples/output/experience\_jumelle/HV\_PFT1/fluxes/E\_netrad\_init\_HV.dat

savestate H\_soil\_mean 1 ij 0 A 3 ./examples/output/experience\_jumelle/HV\_PFT1/fluxes/H\_bqsb\_init\_HV.dat

savestate H\_soil\_mean 2 ij 0 A 3 ./examples/output/experience\_jumelle/HV\_PFT1/fluxes/H\_gqsb\_init\_HV.dat

Figure 5. Minimization phase

* Ir order to launch the twin experiment, we start by adding a random noise to the control parameters, the idea at the of the assimilation process is to retrieve their initial value (1 for all parameters)
* Before the assimilation, a forward is run with the perturbed paraemreters value in order to save at the the first guess

########################## Minimization ##############################

print\_cost ON

setm\_impres 0

setm\_io 6

setm\_mode 0

set\_nbiter 100

setm\_nsim 200

setm\_dxmin 2.0e-30

setm\_epsg 2.0e-20

setm\_ddf1 1.0

#set\_qs\_parts 4

runm

###################### After optimization ######################

set\_modeltime 0

FORWARD

set\_modeltime 0

###############################################################################

######################### 4) Savings parameters ###############################

###############################################################################

################################# Saving Parameters after assimilation #######################

savestate z0\_c 1 i 0 A 1 ./examples/output/experience\_jumelle/HV\_PFT1/param/z0\_fin\_HV.dat

savestate so\_cond\_c 1 i 0 A 1 ./examples/output/experience\_jumelle/HV\_PFT1/param/so\_cond\_fin\_HV.dat

savestate so\_capa\_c 1 i 0 A 1 ./examples/output/experience\_jumelle/HV\_PFT1/param/so\_capa\_fin\_HV.dat

savestate emis\_c 1 i 0 A 1 ./examples/output/experience\_jumelle/HV\_PFT1/param/emis\_fin\_HV.dat

savestate albvis\_c 1 i 0 A 1 ./examples/output/experience\_jumelle/HV\_PFT1/param/albvis\_fin\_HV.dat

savestate rsol\_c 1 i 0 A 1 ./examples/output/experience\_jumelle/HV\_PFT1/param/rsol\_c\_fin\_HV.dat

savestate so\_capa\_c 1 i 0 A 1 ./examples/output/experience\_jumelle/HV\_PFT1/param/so\_capa\_fin\_HV.dat

savestate so\_cond\_c 1 i 0 A 1 ./examples/output/experience\_jumelle/HV\_PFT1/param/so\_cond\_fin\_HV.dat

savestate mx\_eau\_c 1 i 0 A 1 ./examples/output/experience\_jumelle/HV\_PFT1/param/mx\_eau\_fin\_HV.dat

savestate dpu\_c 1 i 0 A 1 ./examples/output/experience\_jumelle/HV\_PFT1/param/dpu\_fin\_HV.dat

savestate hum\_c\_12 1 i 0 A 1 ./examples/output/experience\_jumelle/HV\_PFT1/param/hum\_fin\_HV.dat

################################# Saving Model state after assimilation #######################

savestate E\_tempsol 1 i 0 A 3 ./examples/output/experience\_jumelle/HV\_PFT1/fluxes/E\_tempsol\_fin\_HV.dat

savestate E\_fluxsens 1 i 0 A 3 ./examples/output/experience\_jumelle/HV\_PFT1/fluxes/E\_fluxsens\_fin\_HV.dat

savestate E\_fluxlat 1 i 0 A 3 ./examples/output/experience\_jumelle/HV\_PFT1/fluxes/E\_fluxlat\_fin\_HV.dat

savestate H\_soil\_humrel1 1 i 0 A 3 ./examples/output/experience\_jumelle/HV\_PFT1/fluxes/E\_humrel\_fin\_HV.dat

savestate T\_coef\_diff 2 i 0 A 3 ./examples/output/experience\_jumelle/HV\_PFT1/fluxes/T\_soilflx\_fin\_HV.dat

savestate E\_netrad 1 i 0 A 3 ./examples/output/experience\_jumelle/HV\_PFT1/fluxes/E\_netrad\_fin\_HV.dat

savestate H\_soil\_mean 1 ij 0 A 3 ./examples/output/experience\_jumelle/HV\_PFT1/fluxes/H\_bqsb\_fin\_HV.dat

savestate H\_soil\_mean 2 ij 0 A 3 ./examples/output/experience\_jumelle/HV\_PFT1/fluxes/H\_gqsb\_fin\_HV.dat

################################# Plotting all outputs #######################

####some model variables

!gnuplot ./examples/output/experience\_jumelle/HV\_PFT1/plot\_variables\_HV\_PFT1.gp

####control paremeter variation

!gnuplot ./examples/output/experience\_jumelle/HV\_PFT1/plot\_parameters\_HV\_PFT1.gp

Figure 6. Assimilation procedure

The maximization process is then run with the command “*runm*”. The options before this command are specific options for the minimizer used (M1QN3). For more information consult Gilbert et al (2009).

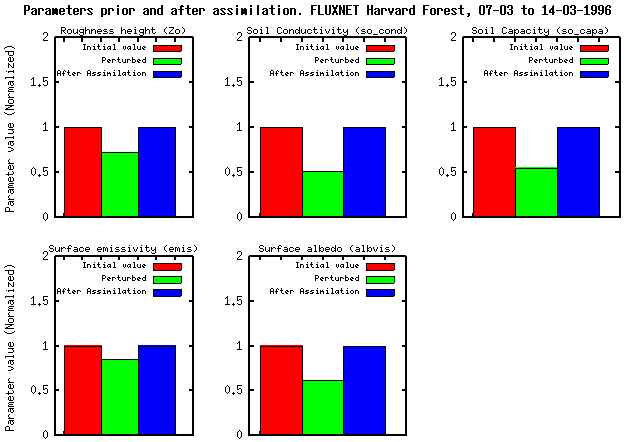
Once the minimization process is finish, we retrieve the control parameter values that generated the synthetic observations. A final FORWARD is run in order to retrieve the final model state. All variables and parameters are store (with the command *savestate*) and two plots are shown at the end, using *gnuplot*. The gnuplot output can be supressed by adding *#* at the beginning of the *!gnuplot* command

Figure 7. Parameters value prior and after assimilation for experiment 1.

Figure 7 shows the evolution of the control parameters: its optimal values, the perturbed values and the final value after assimilation. It can be observed that the initial parameter value (red bars) and the final value after assimilation (blue bars) are identical, showing that the initial control parameter values, before perturbation, were retrieved successfully.

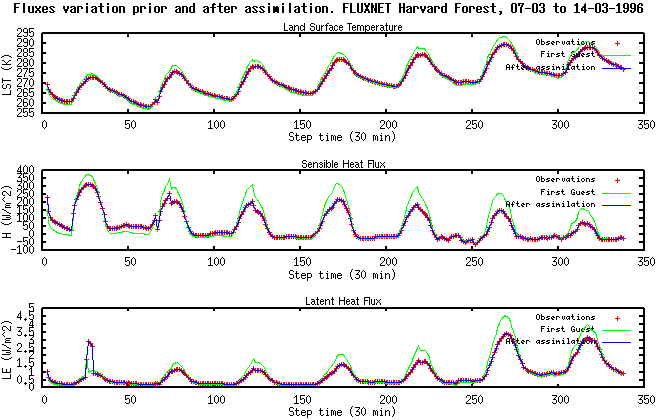


Figure 8. Variable variation prior and after assimilation for experiment 1

The evolution of some model state variables prior and after assimilation are shown in Figure 8. The Red dots in figure 8 corresponds to the available observations each time step. The green curve represents the first guess: the variable values estimated with the perturbed parameters. Finally the blue curves are the estimated variables using the parameters final values afeter the assimilation process. As it can be observed, blue and red curve are perfect match, showing that the initial parameter values that generated the observations were retrieved with the assimilation.

# 3. SECHIBA-YAO Outputs

Besides the variables and parameters outputs presented in Fig.8 and Fig.9, SECHIBA-YAO computes several model state variables: net radiation (Rn), soil heat flox (Q) and soil water reservoir contents (water stress). All the outputs are available for the user and they are included in the folder *./examples/output/experience\_jumelle*. User can take the different output files and perform their own comparisons.

The extension of SECHIBA-YAO output files is .dat. The format of the files generated with SECHIBA-YAO is presented in the table 1.

|  |  |  |
| --- | --- | --- |
| 1 | 1 | 273.5 |
| Its a temporal axis  It represents the step time | Its a space axis.  It represents the x-axis | Its the variable output value. In this case is the soil temperature in step time 1 and in x-axis 1, since its a 1-dimension variable |

Table 1. SECHIBA-YAO file format

* For variables Q, Rn, H, LE and LST, their output file correspond to the one presented in Table 1
* For the parameters, since its an unique value, only two columns are presented with only one line, corresponding to the parameter value.
* File does not have the entitled of the columns

## References

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