SURFEX TRAINING COURSE EXERCISES

Physiography, initialization, 1D and 2D cases

1 – PHYSIOGRAPHY (PGD)

2 – INITIALIZATION (PREP)

3 – 1D EXPERIMENTS

     A. ISBA : vegetation scheme

     B. FLAKE : lake model

     C. TEB : town scheme

     D. ISBA/SNOW : snow scheme

     E. ISBA/HYDRO : Subgrid options in hydrology

4 – 2D EXPERIMENT

The reference documentation is available on the surfer site :
 http://www.cnrm.meteo.fr/surfex/spip.php?rubrique10
You can use the search engine to rapidly find information on variables, namelist ...

The documents of the courses are available on the SURFEX site :
 http://www.cnrm.meteo.fr/surfex/spip.php?rubrique142

TOOLS :

● SURFEX environment :make_useful_links.sh (to create appropriate links for physiography)

● Graphics : Draw.py can be used for all exercises. Draw needs a configuration file : conf.cfg. See the tutorial at the end of the document

1 . PHYSIOGRAPHY

- First go to the **surfex_training/pgd/cuba** directory where prepared experiment is ready. The main namelist is named OPTIONS.nam. Make the links to the physiography files, the cover data and the surfex binaries using the script make_useful_links.sh.

- Run ./pgd.exe

  - The main output file is PGD.txt. Look at the file and the variables stored (gedit)

  - How many COVERS are present in the domain?

  - An other output file is class_data_cover.tex which describes COVERS. Use latex and xdvi to visualize it. (latex clas_data_cover.tex / xdvi class_data_cover.dvi)
    What the fraction of town and nature for cover 160? What is the fraction of town and nature for cover 202? Which types of vegetation are present in covers 160 and 202?

  - Plot COVERS, orography (ZS), fraction of the 4 tiles (FRAC_SEA, FRAC_NATURE, FRAC_TOWN, FRAC_WATER, fraction of sand (SAND), fraction of clay (CLAY)...

  - In OPTIONS.nam, a uniform value for ZS is prescribed. Change OPTIONS.nam in order to use the topographic file gotopo30.
    Rerun the PGD and plot the new orography.

  - Plot the sand and clay fraction. Fractions of sand and clay are also defined as uniform values in OPTIONS.nam. Define sand and clay fractions from FAO database. Rerun PGD and plot new sand and clay fractions.

  - Change geographical area, projection, number of points….
    Rerun PGD and visualize data over your new domain.

2. INITIALIZATION

Once you have achieved the « PGD » experiment, make a copy of the ouput PGD.txt file and the OPTIONS.nam namelist file into the directory named **surfex_training/prep**. Don't forget to rerun make_useful_links.sh The goal is now to initialize the model variables for vegetation, town, etc.

- The first step is the modification of OPTIONS.nam to choose the configuration for the initialization of model variables. In the « prep » directory is NAMELIST_PREP.nam : all namelist instructions contained in this file have to be copied into OPTIONS.nam.

  ➢ You can for example use the « cat » command to add the content of NAMELIST_PREP.nam into OPTIONS.nam (cat NAMELIST_PREP.nam >> OPTIONS.nam)

- The second step consists in running « prep.exe » to produce PREP.txt file. Look at the variables in PREP.txt, Plot for example the continental surface temperature TG1P1, first roof layer temperature TROOF1, sea surface temperature SST

- The third step will allow you to modifiy the way the initialization is done : up to now what you have done is to affect a constant value for all model variables. This is done in the namelist NAM_PREP_* for each tiles with constant values. See OPTIONS.nam. This is of course not suitable for 2d cases.

  ➢ Change the namelist OPTIONS.nam to account for an atmospheric file (arpifs.AN.20050719.00) from which information will be read and adapted to your grid. The file format is grib. Hints can be found at
  http://www.umr-cnrm.fr/surfex//spip.php?article65
  http://www.umr-cnrm.fr/surfex//spip.php?article69
  http://www.umr-cnrm.fr/surfex//spip.php?article72

- Finally, rerun prep and verify the content of PREP.txt file. Plot for example the continental surface temperature TG1P1, first roof layer temperature T_ROOF1, sea surface temperature SST.

3. 1D EXPERIMENTS

A - ISBA : vegetation scheme (directory "isba")

A first exercise for 1D runs with the ISBA scheme

A.1: run the reference simulation: pgd, prep and offline. Save output files in a separate directory (ref) for later comparison. Output files (*.TXT) can be plot with Draw.py and conf.cfg files:

```
[Conf]
kind= C1d
nbfig=1

[Fig1]
path =/home/.../TG1.TXT
field=
expe=
(TG1 being surface temperature)
```

A.2: start from reference simulation and modify soil moisture initial state (decrease soil wetness index by 10%) in OPTIONS.nam. Save output in separate directory (exp1). Plot root water content (WG2) for simulations 'ref' (A.1) and 'exp1' (A.2) using for example:

```
[Conf]
kind= C1d
nbfig=2

[Fig1]
path =/home/.../ref/WG2.TXT
field=
expe=ref

[Fig2]
path =/home/.../exp1/WG2.TXT
field=
expe=exp1
```

How long does it take to return to the reference simulation values? What is the impact on the bottom drainage?

A.3: introduce the VIC (Duemesnil and Todini, 1992) formulation for subgrid surface runoff in OPTIONS.nam. (CRUNOFF = 'DT92' in the ISBA subgrid hydrology namelist). Save output in a separate directory (exp2). Evaluate the impact on runoff (RUNOFFC_ISBA), drainage (DRAINC_ISBA), and water content (WG2), by comparison with exp1.

```
[Conf]
kind= C1d
nbfig=2

[Fig1]
path =/home/.../exp1/DRAINC_ISBA.TXT
```

```
field=
expe=ref

[Fig2]
path =/home/.../exp2/DRAINC_ISBA.TXT
field=
expe=exp2
```

A.4: What is the value of the thermal inertia coefficient in OPTIONS.nam?
   Modify the thermal coefficient Cv (K.m2/J) in OPTIONS.nam with Cv=0.00002 (save output in
     directory expcv2) and Cv=0.000005 (save output in directory expcv05)
   Evaluate the impact on surface temperature:
   Plot surface temperature.

```
[Conf]
kind= C1d
nbfig=3

[Fig1]
path =/home/.../exp2/TG1.TXT
field=
expe=exp2

[Fig2]
path =/home/.../expcv2/TG1.TXT
field=
expe=expcv2

[Fig3]
path =/home/.../expcv05/TG1.TXT
field=
expe=expcv05
```

A.5: What is the impact in terms of surface latent heat (LE) and sensible heat (H) fluxes?

B - FLake : lake model (directory "thaumex")

Exploring the Flake model for lakes. Exercise based on data from an experiment in the Thau laguna in the South of France.

Simulation of the surface temperature diurnal cycle...

B.1 : Copy OPTIONS.nam_REF into OPTIONS.nam and modify it to run WATFLUX model (see NAM_PGD_SCHEMES). Save output files (*.TXT) in a separate directory.

B.2 : Change OPTIONS.nam and modify it to run FLAKE model (see NAM_PGD_SCHEMES). Save output files (*.TXT) in a separate directory. This is now the reference experiment.

B.3 : Plot surface temperature TS_WATER.TXT for WATFLUX and FLAKE experiments and the measured one T10CM_K.dat.

NB : you can use Draw.py to compare simulation results with the observations. See the example below for conf.cfg :

```
[Conf]
kind= C1d
nbfig=3

[Fig1]
path =/home/.../thaumex/watflux/TS_WATER.TXT
field=
expe=watflx

[Fig2]
path =/home/.../thaumex/flake/TS_WATER.TXT
field=
expe=flake

[Fig3]
path =/home/.../thaumex/obs/T10CM_K.dat
field=
expe=obs
```

Sensitivity to the total lake depth...

B.4 : In the reference experiment (defined in B.2) the total lake depth equals 4m. Make 2 experiments with a lake depth of 2m and 20m respectively. Save output in separate directories.

B.5 : Plot lake surface temperature for experiments with 2m, 4m and 20m.

B.6 : Plot the mixed layer depth H_ML.TXT

Sensitivity to extinction coefficient...

B.7 : From the reference experiment defined in B.2, make 2 experiments where extinction coefficient equals $0.3m^{-1}$ and $2.4m^{-1}$

B.8 : Plot lake surface temperature for these experiments and compare to the reference.

B.9 : Plot mixed layer depth for these experiments and compare to the reference and compare to the reference.

More diagnostics...

B.10 : Add temperature profile as FLake diagnostics (info available in surfex website) and plot temperatures at depths 0m, 5m, 10m, 15m, 20m on the same graph for the B4 run with 20m as lake depth.

C – Teb : town scheme (directory "ma01")

The various options of TEB

C.0 : Save the namelist OPTIONS.nam in a file OPTIONS.nam_ref.

C.1 : Run the reference experiment, by executing pgd, prep and offline ; save the output files in a directory « REF ».

Urban vegetation

C.2 : GARDEN :copy OPTIONS.nam_ref in OPTIONS.nam and open namelist OPTIONS.nam. Set LGARDEN=T in NAM_PGD_SCHEMES to activate the TEB-GARDEN scheme. Rerun the experiment, from pgd.exe to offline.exe. Move output TXT files in a directory GARDEN.

Plot LE_TEB.TXT for REF and GARDEN :

Observations ?

The building energy model BEM

C.3 : BEM : copy OPTIONS.nam_ref in OPTIONS.nam and open namelist OPTIONS.nam. Set CBEM='BEM' in NAM_TEB to activate the BEM scheme. Rerun the experiment, from pgd.exe to offline.exe. Move output TXT files in a directory BEM.

Plot TI_BLD.TXT and TCANYON.TXT for REF and BEM :

C.4 : BEM-DXCOIL : open OPTIONS.nam from C.3. and change CCOOL_COIL='IDEAL' to CCOOL_COIL='DXCOIL'. Rerun the experiment, from pgd.exe to offline.exe. Move output TXT files in a directory DXCOIL.

Plot TI_BLD.TXT and TCANYON.TXT for BEM and DXCOIL :

C.5. BEM-DXCOIL-AUTOSIZE : open OPTIONS.nam from C.4. and change LAUTOSIZE = F to LAUTOSIZE = T. Rerun the experiment, from pgd.exe to offline.exe. Move output TXT files in a directory AUTOSIZE.

Plot TI_BLD.TXT and TCANYON.TXT for DXCOIL and AUTOSIZE :

Impact of town geometry

C.6 : ORIE : copy OPTIONS.nam_ref in OPTIONS.nam and open namelist OPTIONS.nam. Set NTEB_PATCH=3 in NAM_TEB and CROAD_DIR='ORIE' in NAM_PREP_TEB. Rerun the experiment, from pgd.exe to offline.exe. Move output TXT files in a directory ORIE.

Plot TROAD1 for the 3 teb patches (ie for the 3 road orientations) :

ORIE/T1_TROAD1.TXT (0 degree) ORIE/T2_TROAD1.TXT (60 degrees) and ORIE/T3_TROAD1.TXT (120 degrees)

C.7 : ORIE+TWO : open namelist OPTIONS.nam from C.6. Set CWALL_OPT='TWO' in NAM_PREP_TEB. Rerun the experiment, from pgd.exe to offline.exe. Move output TXT files in a directory 2WALL.

Plot ORIE/T1_TWALL1.TXT, 2WALL/T1_TWALLA1.TXT and 2WALL/T1_TWALLB1.TXT

D - isba/snow : snow scheme (directory "isba_snow")

The ISBA snow schemes and the heat fluxes between the snow and the soil

D.1 : *Look at the namelist OPTIONS.nam :*

What is the scheme for the soil and vegetation? What is the number of soil layers and total soil depth? the root depth? The percentage of vegetation in the grid? The snow scheme?

D.2 : *Run the reference simulation :*

Run pgd, prep and offline. Plot snow depth (DSN_T_ISBA.TXT), snow water equivalent (WSN_T_ISBA.TXT), temperature of the first soil level (TG1), surface temperature (TS_ISBA) and cumulative snow melt (SNOWMLTC_ISBA).
Save output TXT files in a separate directory (ref) for further comparisons.

D.3 : *Modify the initial state of the soil :*

Add 5K to XTG_ROOT and XTG_DEEP.

Run pgd/prep/offline and save the outputs in a separate directory (5k)
Compare the soil temperatures (TG1, TG10, …) with the reference simulation.
Compare the snow variables: snow depth (DSN_T_ISBA), snow water equivalent (WSN_T_ISBA), snow melt (SNOMLTC_ISBA) with the reference simulation.

D.4 : *Comparison with vegetation:*

Return to the reference values for XTG_ROOT and XTG_DEEP. In the previous experiments, snow was assumed to cover all the ground, as soon as it is present (the snow fraction PSN_ISBA = 1). This is forced by LSNOW_FRAC_TOT = T in NAM_PREP_ISBA_SNOW. Change this option to F (→ PSN will vary according to the vegetation LAI and snow water equivalent). Save the outputs in a different directory (veg)
Plot the snow fraction (PSN_ISBA)
Compare WSNOW, TG1, TS_ISBA with the reference run.
How do you explain the differences on snow cover?

D.5 : *Comparison with a simple soil and snow scheme :*

Rename OPTIONS.nam (→ OPTIONS.nam_CRO). Copy OPTIONS.nam_D95 to OPTIONS.nam (look at this namelist : soil and snow model, soil depth, …).

Run pgd, prep and offline and save the output in a different directory (d95)

Plot the snow water equivalent (WSN_T_ISBA kg/m2) for experiment d95 and ref.
Compare TG1, TG2 and TS_ISBA with the reference simulation. What is the significance of the variables in both cases?

E - isba_hydro : Subgrid options in hydrology (directory "isba_hydro")

The exercise is based on a 1500 km2 basin in Southwest of France ([Aveyron - Laguepie](#))
Forcing files are extracted from the SAFRAN analysis.

The observed discharge is compared to the SURFEX runoff: surface runoff (RUNOFF) + drainage (DRAIN). The basin is small and observations are at daily time step, that's why ISBA runoff is directly compared to discharge (no hydrological model for routing). Even if only one point is simulated, the namelist makes use of the standard databases and simulated one grid point of 8x8 km, as for spatialized hydrological applications.

Graphics : in addition to Draw.py :

- *discharge.py compares the observed and simulated discharges*

- *compare_discharge.py compares several runs stores in several directories with observations. You need to edit this file, line rep=[...] to specifies which experiments will be compared.*

Namelists: two namelists are provided. The exercise can be done with the two namelists.

- *OPTIONS.nam_3-L_BASIC: 3L (3 layers) version without any subgrid runoff parameterization.*

- *OPTIONS.nam_DIF: multi-layer soil with subgrid runoff (used in the Safran-Isba-Modcou chain).*

    E.1 : Copy OPTIONS.nam_3-L_BASIC → OPTIONS.nam.
        Run pgd.exe, prep.exe and offline.exe to create a reference run.
        Use discharge.py to plot the simulated and observed discharge.
        Save the results in a specific directory (ref).

    → *Impact of subgrid hydrology options : the documentation can be found in the SURFEX website (NAM_ISBA for RUNOFFB, WDRAIN, NAM_SGH_ISBA for the other options)*

    E.2 : Switch on the DT92 subgrid runoff run with various RUNOFFB (around 0.5, save the results in a separate directory and
        switch on the the exponential profile of KSAT (CKSAT='SGH'),
        add a subgrid drainage (XUNIF_WDRAIN= 0.001 or other values),
        change the number of patches from 1 to 12.
        At each step, compare the impact of different runs using compare_discharge.py

You can also try to use the multilayer model DIF (second namelist)

4. 2D EXPERIMENT

Go to the "2Dcase" directory. This exercise is a 2D case, over France, at 1° resolution. Forcing file is from March to July 1979.

1. Comparison water/nature

1.1 FLake model is activated for tile 'water', and ISBA for tile 'nature'. Run pgd, prep and offline.

Plot the water fraction and the nature fraction in the domain with Draw_2D.py and conf2.cfg

```
[Conf]
kind= Map
nbfig=2

[Fig1]
path =PGD.nc
field= FRAC_NATURE
expe=
day=0

[Fig2]
path =PGD.nc
field=FRAC_WATER
expe=
day=0
```

1.2 A grid point can have a nature fraction and a water fraction. Plot the surface temperature for water and nature for a grid point where both tiles are present.

```
[Conf]
kind= C1d
nbfig=2

[Fig1]
path =FLAKE_PROGNOSTIC.OUT.nc
field= TS_WATER
expe=
day=

[Fig2]
path =ISBA_DIAGNOSTICS.OUT.nc
field=TSRAD_ISBA
expe=
day=
```

1.3 Plot the latent heat flux for water and nature (in *DIAGNOSTICS.OUT.nc files, LE_WAT and LE_ISBA variable)

2. Evolving Leaf Area Index (LAI)

2.1 Copy FORCING.nc file in AST directory. Go to the "2Dcase/AST/" directory. In this experiment, the option "CPHOTO=AST" is activated and climatology of LAI (prescribed in ECOCLIMAP) is used. Run offline.exe

You can visualize the time evolution of LAI with 'ncview ISBA_DIAGNOSTICS.OUT.nc'. Click on LAI_ISBA, and click on the date or on the play button. You can visualize the evolution of LAI for each PATCH in the file ISBA_VEG_EVOLUTION.OUT.nc

2.2 Copy FORCING.nc file in NIT directory. Go to the "2Dcase/NIT/" directory.

In OPTIONS.nam, change the type of photosynthesis physics, by replacing 'CPHOTO=AST' by 'CPHOTO=NIT'. 'NIT' option is able to dynamically simulate LAI. Run offline.exe

Visualise the evolution of LAI by grid point (LAI_ISBA in ISBA_DIAGNOSTICS.OUT.nc) or by PATCH in ISBA_PRONOSTICS.OUT.nc

2.3 Compare LAI values for trees (PATCH4) for a given day (e.g. day=50 or 150) between the two experiments.

```
[Conf]
kind= Map
nbfig=3

[Fig1]
path =AST/ISBA_VEG_EVOLUTION.OUT.nc
field= LAIP10
expe=AST
day=150

[Fig2]
path =NIT/ISBA_PROGNOSTIC.OUT.nc
field=LAIP10
expe=NIT
day=150

[Fig3]
path =
field = diff
expe=
day=
```

2.4 Compare evapotranspiration (LETR_P4, in ISBA_DIAGNOSTICS.OUT.nc) for the same days.

Annex : Draw Tutorial

Draw handle two types of data, 1d series and Orographic maps from TXT and Netcdf files

It works with a configuration file conf.cfg by default based on the following format:

```
[Conf]
kind= C1d  (or Map)
nbfig=2  number of dot plots (only for C1d)

[Fig1]
path =pathname
field= field to extract  needed for Netcdf or PGD files, empty for unbundle
file ( ex TG1.TXT )
 expe= name of the experience for the label on the plot  (needed
for C1d only)

[Fig2]
path =pathname
field= field to extract   needed for Netcdf or PGD files, empty for unbundle
file ( ex TG1.TXT )
expe=
...
```

- C1d for 1d data
- Map means data is based on x,y,z vectors
- x and y correspond to XLON and XLAT data found in PGD file

Cfg file examples

Maps for Physiographic data

TXT output

```
[Conf]
kind= Map
nbfig=1

[Fig1]
path =/home/.../PGD.txt
field= ZS
```

NETCDF output

```
[Conf]
kind= Map
nbfig=1

[Fig1]
path =/home/.../PGD.nc
field= ZS
```

1d series

TXT output

```
[Conf]
kind= C1d
nbfig=2

[Fig1]
path =/home/.../ref/WG2.TXT
field=
expe=ref

[Fig2]
path =/home/.../exp/WG2.TXT
field=
expe=exp
```

NETCDF output

```
[Conf]
kind= C1d
nbfig=2

[Fig1]
path =/home/.../ref/ISBA_PROGNOSTIC.OUT.nc
field= WG2
expe=ref

[Fig2]
path =/home/.../exp/ISBA_PROGNOSTIC.OUT.nc
field= WG2
expe=exp
```