An introduction to SURFEX
# Program of the course

**Formation Permanente**

**Stage:** SURFEX Practical training  
04/11/2014 - 07/11/2014  
salle: C059

<table>
<thead>
<tr>
<th>Time</th>
<th>Tuesday Mardi 04/11/2014</th>
<th>Wednesday 05/11/2014</th>
<th>Thursday Jeudi 06/11/2014</th>
<th>Friday Vendredi 07/11/2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>08:45</td>
<td>General presentation of SURFEX (E. Martin)</td>
<td>Lakes and Oceans (P. Le Moigne)</td>
<td>Practical exercise (continued): ISBA/Town/FLAKE/ASSIM (S. Faroux, P. Le Moigne)</td>
<td>Conclusion and evaluation of the course (E. Martin, P. Le Moigne, S. Faroux)</td>
</tr>
<tr>
<td>09:30</td>
<td>Installation of SURFEX (S. Faroux)</td>
<td>Break</td>
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<tr>
<td>10:45</td>
<td>Break</td>
<td>Break</td>
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<tr>
<td>12:15</td>
<td>Lunch</td>
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<tr>
<td>14:00</td>
<td>ECOCLUMAP and PGD (S. Faroux)</td>
<td>Practical exercise: Nature scheme (ISBA) (S. Faroux, E. Martin, S. Dasprez)</td>
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<td></td>
</tr>
</tbody>
</table>

**Responsable de la session:** Eric Martin, S. Faroux, P. Le Moigne, S. Dasprez (CNRM)  
**Semaine du 03/11/2014 au 07/11/2014**

**Attestation of stage?**

**SURFEX course**
Documentation for the course:

Presentation and exercises:
http://www.cnrm.meteo.fr/surfex/spip.php?article29

Documentation: scientific documentation and user's guide (efficient research tool) export versions, bugfixes, etc.:
http://www.cnrm.meteo.fr/surfex-lab/

Two different web sites are used for SURFEX:

Internet: http://www.cnrm.meteo.fr/surfex/

Filtered on IP address: http://www.cnrm.meteo.fr/surfex-lab/
- Provide sufex-support@meteo.fr your IP address (if outside Meteo-France)
Outline

- Introduction – main principles
- Physics
- Description of the surface (tiles – patches – databases)
- Interface with the atmosphere
- Running SURFEX
Main Principles
Let's begin, what is SURFEX?

SURFEX means « surface externalisée »

SURFEX is a code that represents the surface processes.

SURFEX is « externalized », this means that the code can be used inside a meteorological or climate model, or in stand alone (offline) mode.

SURFEX has a modular structure and can include new parametrisations or schemes.
Why do we need externalised surface codes?

- The aim of a surface code is to simulate the fluxes between the surface and the atmosphere: energy, water, carbon, dust, snow, chemical species...

- The surface code needs to simulate processes « below » or « inside » the surface to provide this fluxes.

- Surface codes are improved and validated offline, many works on surface processes are done by people not belonging to the meteorological or climatological communities.

- The use of the same code for coupled and offline application is mandatory in order to ensure the coherency between the two applications.

- Need to externalise the surface code of the atmospheric model. I.e. clearly separate them from other part of the code in order to run them in stand alone mode.
Coupling and interfaces

Forçages

Atmosphere

Surface fluxes

Other variables

SurfEx

The science is here!

I/O monitoring

One coupling scheme allowing Explicit or implicit coupling

Limited exchanges of variables

I/O

Low level routine only depends on the output format
SURFEX : history

~2000 : Initial decision : building of SURFEX on the base of the existing ISBA/TEB codes
  Échelles : 1 m ➔ 300 km
  Use : numerical weather forecast, climatic runs, monitoring, reanalysis, process studies.

2005 : V1 : Méso-NH, AROME
2008 : coupling with TRIP
2009 : Extended Kalmn filter
2009 : FLake
2010 : coupling with Top-Model
2010 : CNRM-CM5.1
2010/2011 : ALADIN, assimilation (OI) for ALADIN et AROME
2011 : Surfex Scientific committee : CNRM (GMAP, GMGEC, GMME), Méso-NH, ALADIN, HIRLAM.
2011 : CROCUS
2012 : SODA (Surfex offline data assimilation)
2013 : TEB/BEM (building energy model)
2015 : ISBA/MEB, use of OASIS for coupling with hydrology and ocean models
## Versions and correspondence with atmospheric models versions

<table>
<thead>
<tr>
<th>SFX</th>
<th>release</th>
<th>NWP</th>
<th>MNH</th>
<th>CNRM-CM</th>
</tr>
</thead>
<tbody>
<tr>
<td>V1</td>
<td>2005</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V4.8</td>
<td>2008</td>
<td>CY35t2</td>
<td>V4.8</td>
<td></td>
</tr>
<tr>
<td>V5.8</td>
<td>2009</td>
<td>CY36t1</td>
<td></td>
<td>CM5 (CY32+V5.8)</td>
</tr>
<tr>
<td>V6</td>
<td>2010</td>
<td>CY37t1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>V7.1</td>
<td>2011</td>
<td></td>
<td>V4.9</td>
<td></td>
</tr>
<tr>
<td>V7.2</td>
<td>Feb 2012</td>
<td>CY38t1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>V7.2.1</td>
<td>Jan 2013</td>
<td>CY39t1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>V7.3</td>
<td>Feb. 2013</td>
<td>CY40t1</td>
<td>V4.10</td>
<td></td>
</tr>
<tr>
<td>V8</td>
<td>2015</td>
<td></td>
<td></td>
<td>CM6(CY37t2+V8 or V7.3**)</td>
</tr>
</tbody>
</table>

*V6+ (V6.0+ GMAP optimisations)*  
**CY40t1 and CNRM-CM6 contains additional developments**
Coupled and operational applications based on SURFEX

Atmospheric models:
Mesoscale model Meso-nh
Climate research: ARPEGE – ALADIN
Numerical weather prediction:
  - AROME (2008)
  - ALADIN (2010)
  - Soil analysis (OI_MAIN) 2011
  - ALARO
  - HARMONIE
  - ARPEGE (2015/2016)

Offline operational applications
Snow and avalanches: Safran-Surfex-Mepra (2014)
Hydrology: Safran-Surfex-Modcou (2015/2016)
Four main tiles:
- **Sea**
- **Lakes**
- **Natural surfaces (Nature)**
- **Town**
Physics
Physical schemes

**Sea and oceans**: Prescribed SST, Charnock formula
Mondon and Redelsperger
ECUME (multicampaign parametrisation)
1D ocean model

**Lakes**: Prescribed surface temperatures, Charnock formula
FLake

**Sol/Vegetation**: ISBA
(Interaction Soil Biosphere Atmosphere)

**Town**: TEB (Town Energy Balance)
Canyon Approach,
Detailed radiative scheme
Heat storage in buildings
• ECUME multi-campaign parametrisation (prescribed SST)

• 1D ocean mixing layer model Gaspar et al., 1990
Lakes : Flake model

Simple model, based on assumed shape of the temperature profile

Snow/Ice :
- the ice depth,
- the temperature at the ice upper surface,
- the snow depth, and the temperature at the snow upper surface.

Water / Sediments
- the surface temperature,
- the bottom temperature,
- the mixed-layer depth,
- the shape factor with respect to the temperature profile in the thermocline,
- the depth within bottom sediments penetrated by the thermal wave, and
- the temperature at that depth.

http://nwpi.krc.karelia.ru/flake/

SURFEX course
<table>
<thead>
<tr>
<th>ISBA</th>
<th>Soil</th>
<th>Vegetation</th>
<th>Hydrology</th>
<th>Snow</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Force restore: 2 temperature, 2 or 3 layers for water, icing</td>
<td>Noilhan et Planton 89 (~Jarvis) A-gs (photosynthesis and CO2 fluxes) A-gs and interactive vegetation Slow carbon processes (wood and roots)</td>
<td>No subgrid process Subgrid surface runoff Subgrid drainage Flooding and coupling with TRIP</td>
<td>1 layer, albedo, density variable (ARP/Climat, Douville 95) 1 layer, albedo, density variable (ARP/ALD, Bazile) Multilayer (3, or…) albedo, density, liquid water content (Boone and Etchevers 2000)</td>
</tr>
</tbody>
</table>
Chemical scheme
From local \((dx=1\ \text{km})\) to synoptic scale \((dx=50\ \text{km})\)

http://www.aero.obs-mip.fr/mesonh
The SBL model (Canopy)

without SBL model

Forcing level

humidity

Wind speed

Temp.

Nature tile

Roof wat. res.

Town tile

T roof

T wall

↓ surface heat, momentum and water fluxes ↓

with SBL model

Forcing level

humidity

Wind speed

Temp.

Nature tile

Roof wat. res.

Town tile

T roof

T wall

↓ surface heat, momentum and water fluxes ↓
Describing the surface
How can we represent the surface heterogeneity in a grid?

**Tiling approach:**

- Within a grid mesh, the surface is divided into several homogeneous components.
- Each component receives the same atmospheric forcing.
- Each component calculates fluxes.
- Fluxes are aggregated and returned to the atmosphere.
- No horizontal transfer within the surface.
Tiling in SURFEX:

- The surface is divided into 4 main Tiles, which are treated by different models.
- The tile Nature is divided into 12 patches or natural functional types:

<table>
<thead>
<tr>
<th>Nature</th>
<th>Towns</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea/Oceans</td>
<td>Lakes</td>
</tr>
<tr>
<td>Nature (bare soil/vegetation)</td>
<td></td>
</tr>
<tr>
<td>Towns</td>
<td></td>
</tr>
<tr>
<td>NO no vegetation</td>
<td>C3 (C3 crops)</td>
</tr>
<tr>
<td>ROCK (bare rock)</td>
<td>C4 (C4 crops)</td>
</tr>
<tr>
<td>SNOW (snow and ice)</td>
<td>IRR (irrigated crops)</td>
</tr>
<tr>
<td>TREE (deciduous broadleaved forest)</td>
<td>GRAS (temperate /C3 grassland)</td>
</tr>
<tr>
<td>CONI (evergreen needleleaved forest)</td>
<td>TROG (tropical /C4 grassland)</td>
</tr>
<tr>
<td>EVER (evergreen broadleaved forest)</td>
<td>PARK (wetlands)</td>
</tr>
</tbody>
</table>
Aggregation of functional types is possible in ISBA

<table>
<thead>
<tr>
<th></th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
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<tr>
<td><strong>NO</strong></td>
<td>1</td>
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<tr>
<td><strong>ROCK</strong></td>
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<tr>
<td><strong>SNOW</strong></td>
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<td>2</td>
<td>2</td>
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<tr>
<td><strong>TREE</strong></td>
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<td>3</td>
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<td><strong>CONI</strong></td>
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<td><strong>EVER</strong></td>
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<tr>
<td><strong>C3</strong></td>
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<tr>
<td><strong>C4</strong></td>
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<tr>
<td><strong>IRR</strong></td>
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<td>3</td>
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<tr>
<td><strong>GRAS</strong></td>
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<tr>
<td><strong>TROG</strong></td>
<td>11</td>
<td>10</td>
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<tr>
<td><strong>PARK</strong></td>
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</tbody>
</table>
Physiographic parameters

The surface needs several types of parameters:

- Orography
- Type of the surface (tile) and vegetation types (patches) for « Nature »
  - ISBA: Albedo, leaf area index, soil texture, ...
  - FLAKE: lake depth, extinction coefficient ...
  - SEA Bathymetry
  - ...

Solutions:

- Prescribe the model parameters using a namelist (simple offline runs).
- Databases:
  - Land cover database ECOCLIMAP
  - Topography (e.g. Gtopo30 at 1 km or SRTM for higher resolution, ...
  - Soil properties (clay and sand proportions, organic matters) derived from FAO or HWSD databases.
  - Lake depth and optical water properties (Kourzeneva et al., 2011)
  - Ocean Bathymetry (e.g. Etopo2 from Smith and Sandwell (1997))
ECOCLIMAP: A global database of surface parameters

A land cover map at 1 km resolution in latlon projection
Fully coupled to SURFEX, or available separately)

ECOCLIMAP I: global (215 covers)
ECOCLIMAP II Europe (273 covers)

10-day period surface parameters: LAI, fraction of vegetation veg, roughness length, emissivity, fraction of greeness.

Constant surface parameters: visible / nir / uv albedos, minimum stomatal resistance…
Interface with the atmosphere
Interface with the atmosphere

**ATMOSPHERE**

interface

- radiative properties:
  - albedo
  - emissivity
  - surface radiative temperature

- surface fluxes:
  - momentum
  - sensible heat
  - latent heat
  - CO2
  - chemical species
  - aerosols

- atmospheric forcing:
  - air temperature
  - specific humidity
  - wind components
  - pressure
  - rain rate
  - snow rate
  - CO2, chemical species, aerosols concentration

- radiative forcing:
  - solar radiation
  - infrared radiation

**SURFEX**

\[ \mathcal{F} = f_n \mathcal{F}_n + f_l \mathcal{F}_l + f_t \mathcal{F}_t + f_s \mathcal{F}_s \]

- \( \mathcal{F}_n \) (nature)
- \( \mathcal{F}_l \) (lake)
- \( \mathcal{F}_t \) (town)
- \( \mathcal{F}_s \) (sea)

SURFEX course
Explicit coupling (general case):

variables are provided at $T$ (or $T \rightarrow T+\Delta T$)
Fluxes are returned averaged over $T / T+\Delta T$

Offline: ASCII, binary, Ifi, FA, netcdf standardised interface
(ALMA, Polcher et al., 1998)

http://web.lmd.jussieu.fr/~polcher/ALMA/
Coupled mode: call coupling_surf_atm( variables…)
In case of long time step to avoid instabilities in the coupling with the atmosphere. The surface is called in the middle of the vertical diffusion loop (Best et al., 2004).

\[
X = u, v, \theta, q
\]

\[
X_i^+ - X_i^- = -\alpha_{i,i}(X_{i+1}^+ - X_i^+) + \alpha_{i-1,i}(X_i^+ - X_{i-1}^+)
\]

\[
F_{X,j} = 0
\]

**Vertical diffusion**

**Downward sweep**

\[
X_i^+ = A_{X,i}^- X_{i+1}^+ + B_{X,i}^+
\]

\[
A_{X,i} = f(a_{i,i}, a_{i,j}, A_{X,i-1})
\]

\[
B_{X,i} = f(a_{i,i}, a_{i,j}, B_{X,i-1}, F_{X,i})
\]

**Lower atmospheric level**

\[
X_N^+ = A_{X,N}^- F_{X,S}^+ + B_{X,N}^-
\]

**Surface Ts + Fluxes on each tiles, Average fluxes**

\[
H^+ = \rho C_p V_N^- C_H^- (\beta S T_s^+ - \beta N T_N^+)
\]

\[
\frac{C_s}{\Delta t} (T_s^+ - T_s^-) = R^+ - H^+ - LE^+ - G^-
\]
Interface routines

coupling_surf_atm : packing and call 4 main tiles

coupling_naturen : call of the chosen scheme for the tile
coupling_isba_svatn : choice of method of coupling
coupling_isba_orographyn : subgrid_orography
coupling_isba_canopy : boundary layer
coupling_isban : divide in patches, interactive vegetation, flood, dusts

Isba : energy and water fluxes

All coupling.xxx have the same arguments
More practical ...
Running SURFEX
Running SURFEX

PGD: Physiography
- Choice of surface schemes
- Grid
- physiography

PREP: initialisation of prognostics variables

RUN mode: atmospheric model, offline, ASSIM, DIAG
run and diagnostics
(need atmospheric forcing)
Surface schemes:
Ex for NATURE: NONE, FLUX, TSZ0, ISBA (and options for ISBA)

Grid:
- Gaussian, conformal projection, LONLAT reg, IGN (French Lambert projection), NONE (namelist)
- A part of the grid of an already existing file
- Can be given in fortran argument (ignore namelists)

Physiography:
- Covers: ECOLIMAP or uniform
- Orography (GTOPO30, other files, uniform)
- Sand and Clay fractions (FAO, other file, uniform)
Date of all surface schemes

File to read, or uniform variables (namelist)
OPTIONS for RUN:

General: general options for surface atmosphere
By scheme: options for run (e.g.: subgrid hydrology)

Run: need a PGD file, a PREP file and an atmospheric forcing
Inside « RUN » or autonomously using a surface file and an « instantaneous » forcing.

Defined by namelist (various options) diagnostics aggregated over all the surface, or by tiles, or by patches (nature)
OI_MAIN:
Soil analysis based on Optimal interpolation (Giard and Bazile, 2000, Monthly weather review)
Input: T2m, RH2m

VARASSIM:
Soil analysis based on EKF (Mahfouf et al., 2009, JGR)
Input: T2m, RH2m, wg (satellite) and/or LAI (ISBA-A-gs)

SODA (SURFEX offline data assimilation):
New driver for OI and varassim