The SURFEX project

• the coupling interface between the surface and atmospheric models

• a summary of the physics in Surfex

• perspectives: developments, collaboration,…
Objectives …

• **To develop an ‘externalized’ surface model independent of the atmospheric model:** initialization (parameters and surface variables), time evolution, diagnostics, IO, assimilation

• **To use a ‘general’ coupling interface between the atmosphere and the surface** following the *Best et al.* (2004) concept, but completed during the development of Surfex: the atmosphere only sees the surface fluxes, the coupling can be fully implicit with a ‘tile (d)’ surface scheme

• **To use the ‘tile’ concept for ocean, lake, urban and vegetated areas:** Surfex includes the surface physics developed at CNRM since 20 years

• **To be included in regional and global NWP and research models**

• **In principle, the interface should achieve a plug compatibility for surface parameterizations**! A good test bed for Arome/Aladin-Arpege/Hirlam collaborations ??
Exchanges of flux and atmospheric forcing at each time step

Surfex output as surface boundary conditions for atmospheric radiation and turbulent scheme (additional output needed for the convection scheme)
The tiles and patches in Surfex and Hirlam surface schemes

Atmosphere

Forcing  \( \uparrow \)  Flux

4 tiles with \( f \) tile fixed

\( F_{\text{town}} \)  \( F_{\text{nature}} \)  \( F_{\text{sea}} \)  \( F_{\text{water}} \)

\( f_{\text{town}} \)  \( f_{\text{nature}} \)  \( f_{\text{sea}} \)  \( f_{\text{water}} \)

1, 12 Vegetation patches

SURFEX Workshop, December 2006
The physical schemes to estimate the exchanges of radiation, momentum, heat, water and CO2 fluxes

Sea and ocean:
- prescribed SST, and 3 bulk formulations
- development of a 1D oceanic mixing layer

Lakes:
- prescribed temperature, Charnock formula

Vegetation and soil: ISBA / ISBA-A-gs
(Interface Soil Biosphere Atmosphere)

Town: TEB
(Town Energy Balance)
Climate map

Koepp de Lond 1958
1km: 16 classes

Land cover maps

University of Maryland
1km: 15 classes

Corine land cover
« 250m »: 44 cl.

NDVI profiles

Texture: FAO-10km

215 vegetation types
over the globe

Agrégation

\[ X = \sum \left( f_j \cdot x_j \right) / \sum (f_j) \]

Other data base

Data base for surface parameters

(Masson et al. J. Climate, 2003)
Physics

ISBA:
Soil options:   Force restore, 2 layers , temp, water, ice
                Force restore, 3 layers , temp, water, ice
                Diffusion, N layers , temp, water, ice  Boone, 2000

Vegetation options:
One surface energy budget for vegetation and bare ground
Rs formulation (~Jarvis)  Noilhan and Planton 89
AGS (photosynthesis and CO2 exchanges)  Calvet et al. 1998,
AGS and interactive vegetation  Calvet, 2000

Hydrology options:
no subgrid process  Habets et al. 98
subgrid runoff, subgrid drainage

Snow options:
(i) ‘Arpege’ scheme (1layer, varying albedo)
(ii) 1 layer, varying albedo, varying density  Douville 95
(iii)3 layers, albedo, density, liquid water in snow pack  Boone and Etchevers 2000

Dust emission/deposition:  Grini et al. 2006

Biogenics emissions, chemical dry deposition:  Tulet et al. 2003
Fog forecasting at Paris CDG using the 1D Cobel – Isba model

The 1D Cobel model

Soil temperature forecast

- 20 cm

- 50 cm

- 100 cm

The Isba-df Multi_soil layer version

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Bergot et al. 2005
The ISBA-A-gs version for water/carbon exchanges
A simulation of LAI at the global scale with ISBA – A – gs (off line run with GSWP2 atmos. forcing and ISLSCP data set)

Zonal mean of the maximum of LAI

Gibelin et al. 2006
Atmospheric CO$_2$ modeling with MesoNH coupled with Isba-A-gs (Ceres, may-June 2005)

Simulated CO$_2$ concentrations (ppm) 14H UTC

Comparison of Simulated and observed CO$_2$ concentrations (ppm) 14H UTC

(Sarrat et al., JGR, 2006)
The 3 snow schemes available in ISBA - Surfex

The oper snow scheme (e.g. EBA scheme)

\[ P_{n\,v} + P_{n\,g} \]

\[ T_s (\text{snow + soil}), \ SWE (t), \ \rho \text{ snow} = \text{cst, alb (t)} \]

The Douville (1995) snow scheme used in Arpege – Climat/ Arome

\[ T_s (\text{snow + soil}), \ SWE (t), \ \rho (t), \ \text{alb (t)} \]

The 3 layer explicit snow scheme used in Arome (Boone Etchevers, 2001)

Three pronostic variables for:

- Snow water equivalent $SWE (t)$
- Snow density, $\rho (t)$
- Snow heat content, $H (t)$
Intercomparison of observed/simulated snow depth in the Alps during the Rhône aggreg intercomparison experiment (Boone et al. J. Climate 2004)
Surface Run off and drainage parameterizations

The VIC scheme

Surface runoff

Drainage

Validation with observed river flows

The SIM model

Base flow

Simulated riverflows of large basins

(Habets et al. 99)
Desertic Dust (on-line coupling)

Radiative scheme

Absorption/diffusion of sunlight

Aerosol Scavenging

MesoNH

AROME

Surface cooling

Saltation

SURFEX / ISBA

Grini et al, 2006

SURFEX Workshop, December 2006
Town Energy Balance: physics


- Rain and snow interception
- Radiation trapping
- Latent heat fluxes
- Heat conduction in the materials
- Anthropogenic fluxes

Only 1 road, 1 roof, and 2 identical facing walls
→ ONLY ONE WALL SEB
→ Only one wall temp.
→ Only one road temp.
TEB has been validated on several urban sites:

*Mexico City, Vancouver (Masson et al 2002)*
*Marseille (Lemonsu et al 2003)*

Surface energy budget, observed and simulated
C3. Organization of physical computations

► TEB : Town Energy Balance

Arome forecast valid for 18th of November 2005 midnight

Urban heat Island around Lyon and Toulouse cities

(Y. Seity)
Sea surface fluxes parameterizations

**Bulk parameterizations** $u^*, \theta^*, q^*$:
- **Louis – 79** - formulation $f(Zo, Ri)$
- ‘Unified’ formulation from multi campaign calib. of CdN 10 m (Belamari 2005)
- Toga – **Coare** parameterization (Fairall et al 2003)

*Off-line validation on TOGA-COARE data* (Lebeaupin, 2006)
Sensitivity of simulated convective precipitation on the sea flux formulations in MesoNH: the Aude case

18 h accumulated precipitation

(i) Reduction of momentum and evaporation with UniTFP and Coare formulations

(ii) Low differences in term of precipitation patterns, decrease of precip. accumulation

(Lebeaupin, Ducrocq)
Developpent of a 1D oceanic boundary layer based on TKE (Gaspard et al 1990) in SURFEX

Off line simulation of temperature and Salinity profile

- Equation for T, Salinity, and TKE
- Included the topography
- Initialization from Mercator analysis

(Lebeaupin, 2006)
Status of Surfex implementation at Meteo – France

Arome and MesoNH: implementation with explicit coupling (Isba – 3L + snow 3L + TEB + Ecoclimap)

Aladin, Arpege, Arpege Climat: implementation in 2007 with implicit coupling (Isba 2L + snow OPER + Ecoclimap/923)

SIM and Cobel – Isba: Isba 3L, snow ES, hydrology, A-gs and Isba Df Physics implemented (Off line coupling): Surfex interface be implemented in 2007(?) in SIM
Discussing possible model developments during the workshop:

- Vegetation: Temperature of vegetation canopy?, water stress functions, biomass and carbon components, irrigation module …
- Improvement of the snow/vegetation interactions
- Soils: implementation of the soil diffusion for heat, water and ice, formulation of runoff and drainage…
- Lake modeling (including ice) ?
- Sea ice?
- Urban modelling: improvement of hydrology, canyon meteorology, …
- Sea fluxes, 1D ocean model, 3D ocean model, ?
- Others…. 
Data set used for the development of Surfex

**Snow:** Pilps – Valdai + Snowmip 1 and 2

**Frozen soils:** Illinois -1998

**Vegetation:** the ‘Hapex’ experiments, PILPS (HM86, Cabauw, Lobos, ), Murex and Smosrex (fallow sites), Flux net sites, …

**Hydrology:** SIM, Rhone-AGG, Red - Arkansas, Thornes,…

**Urban physics:** Escompte-Marseille, Capitoul: Toulouse, Mexico, Vancouver,

**Sea fluxes:** Toga-Cooare, Albatros data base (5 field experiments)

**Lakes:** ?
POTENTIAL EMISSION OF MONOTERPENES

NOX EMISSION at 12 UTC in ppp.m/s
General principle

Each model grid box is composed by 4 tiles

1 to 12 patches for the vegetation
Sea surface fluxes parameterizations

« Bulk » sea surface fluxes parameterizations:

\[
\begin{align*}
HF &= \rho_a c_p u_* T_* \\
HF &= \rho_a c_p C_H s(T_0 - T) \\
EF &= \rho_a L_e u_* q_* \\
EF &= \rho_a L_e C_E s(q_0 - q) \\
|\tau_i| &= -\rho_a u_*^2 \\
\tau_i &= -\rho_a C_D s(u_{si} - u_i) \\
\Rightarrow C_H &= \frac{u_* T_*}{s(T_0 - T)} \\
\Rightarrow C_E &= \frac{u_* q_*}{s(q_0 - q)} \\
\Rightarrow C_D &= \left(\frac{u_*}{s}\right)^2 \\
s &= \text{MAX}\left(|\vec{v}_{rel}|, 1\right)
\end{align*}
\]

➢ Direct « bulk » parameterizations: Relationship for the wind between \(u_*, q_*\), \(T_*\) and the rugosity \(z_0\) and the Richardson number \(R_i\) (ex. Louis, 1979)

➢ Iterative « bulk » parameterizations: \(u_*, \theta_*, \text{and } q_*\) from iterations

• \textbf{UNITFP}: unified parameterization with multi-campaign calibration of the exchange coefficients \(C_{D10n}, C_{H10n}, \text{and } C_{E10n}\), (Belamari, 2005);

• \textbf{COARE}: developed from the TOGA-COARE campaign (Fairall et al, 1996), then updated in version 3.0 (Fairall et al, 2003), existing also in a version with a variation of the gustiness parameter \(\beta\) (Mondon et Redelsperger 1998);

...
The externalized surface algorithm?

During run, at each timestep:

Radiative fluxes
- Albedo, Emissivity, radiative temp.
- Momentum fluxes
- Heat flux
- Water vapor flux
- CO2 flux
- Chemical fluxes

Sun position
Atm. Forcing
Rain, snow fall

Surface run

Atmospheric model
surface

SURFEX Workshop, december 2006
A simulation of the snow pack with a Three-layer snow scheme at Col de Porte (Boone, personal communication)

Snow density

Snow depth

Snow Water equi.
Vertical discretisation of the explicit snow scheme

- 3 variable layers
- resolution of thermal and density gradients in snow pack
- liquid water in snow pack and refreezing
- Heat flux at base of snow pack
- Solar flux transmission through snowpack
C3. Organization of physical computations

► ISBA: basic equations

A-gs approach: **the role of stomatal control**

The stomatal aperture controls the ratio:

**Photosynthesis/Transpiration**

according to the environment conditions

Light, temperature, air humidity, soil moisture, atmospheric $[\text{CO}_2]$