SURFEX

Arome training course
Poiana Brasov – November 2005

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Part I. Overview of the externalized surface: theoretical background

A. Introduction to SURFEX

A1. The objectives of SURFEX
A2. How to reach these objectives?
A3. Surface energy budget
A4. Water cycle

B. SURFEX package algorithms

B1. Initialization of physiographic fields
B2. Initialization of prognostic fields
B3. Running surface physical parameterizations

Part I. Overview of the externalized surface: theoretical background

C. Princip of SURFEX

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C2. I/O
C3. Organization of physical computations

Part II. The implementation in Arome and Aladin

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- D2. Explicit coupling
- D3. Implicit coupling
- D4. Type of coupling and model
- D5. Example of coupling

E. Technical aspects

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- E2. Diagnostics
- E3. Physical options

Part I. Overview of the externalized surface: theoretical background

A. Introduction to SURFEX

B. SURFEX package algorithms

C. Princip of SURFEX

A1. The objectives of SURFEX

► The role of surface in a NWP model is to simulate the exchanges of momentum, heat, water, carbon dioxyd concentration or chemical species with the atmosphere. These exchanges are performed by the mean of fluxes.

► An important issue is to separate the surface schemes from the atmospheric model:

- ♦ it allows the use of the same surface code in different atmospheric models: meso-NH, Arome, Arpege/Aladin, ...
- ♦ the switch between surface schemes and options is easy

► Combines different level of complexity in the proposed schemes

- ♦ ideal fluxes approach
- ♦ 2 levels of tiling for surface areas

A2. How to reach these objectives?

- ► Use dedicated physical parameterizations

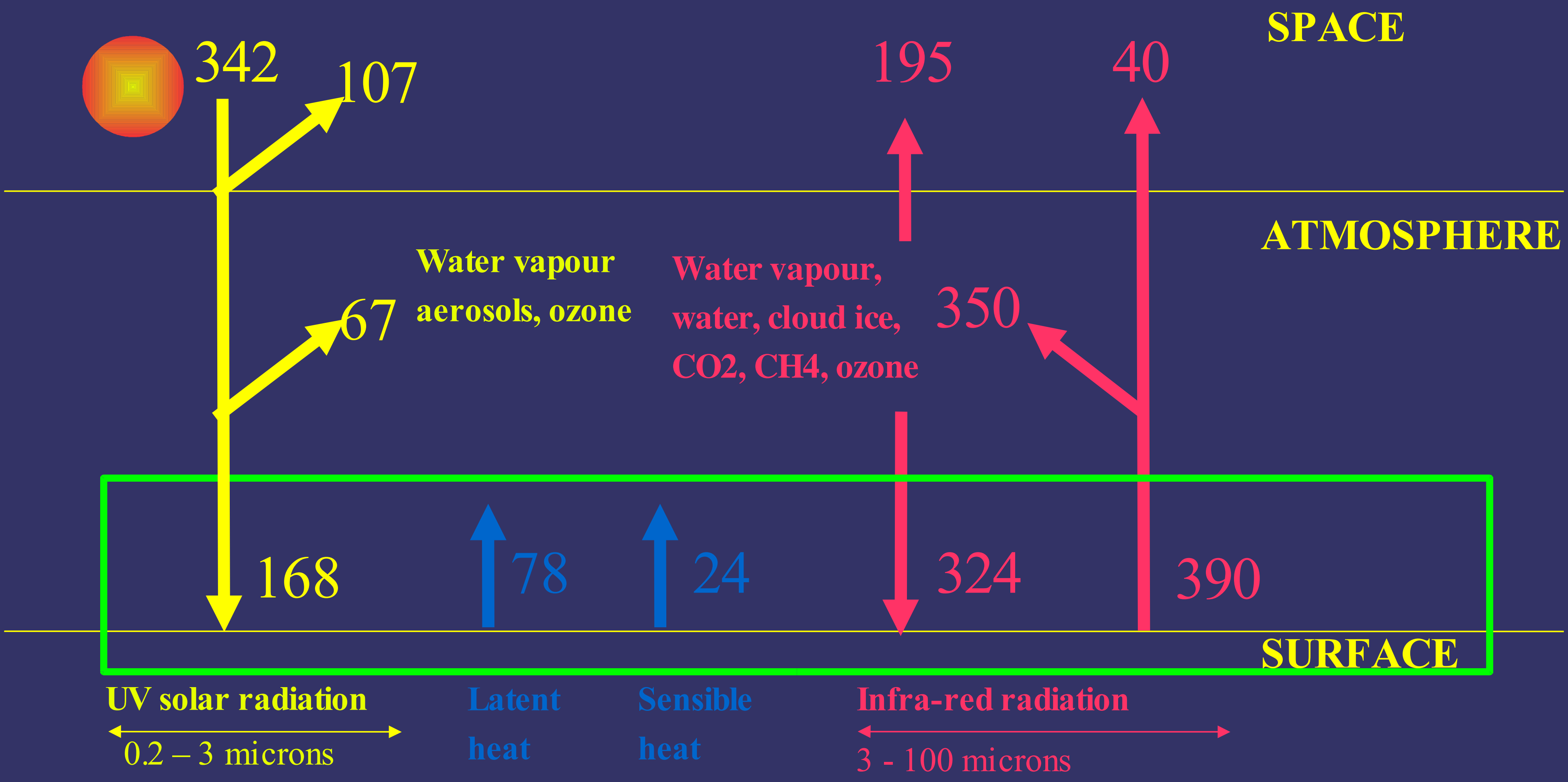
Soil and Vegetation	**ISBA**: Interface Soil Biosphere Atmosphere (Noilhan-Planton 1989, Noilhan-Mahfouf 1996)
Sea and ocean	Prescribed temperature
Town	**TEB**: Town Energy Balance (Masson 2000)
Lake	Prescribed temperature

A2. How to reach these objectives?

- ► Use accurate databases for surface parameters

GTOPO30	**1km Orography**
FAO	**10km texture of soil**
ECOCLIMAP	**1km land surface parameters**

A3. Surface energy budget



SPACE

342

107

195

40

ATMOSPHERE

Water vapour
aerosols, ozone

67

Water vapour,
water, cloud ice,
CO2, CH4, ozone

350

168

78

24

324

390

SURFACE

UV solar radiation

0.2 – 3 microns

Latent
heat

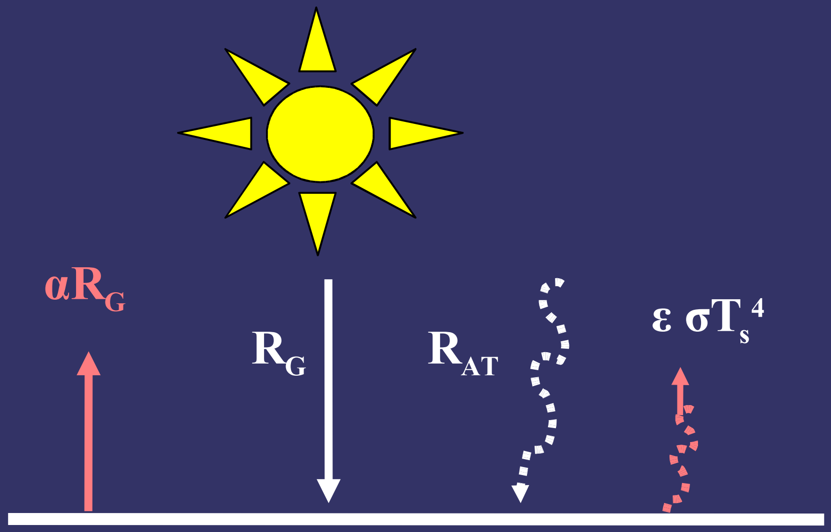
Sensible
heat

Infra-red radiation

3 - 100 microns

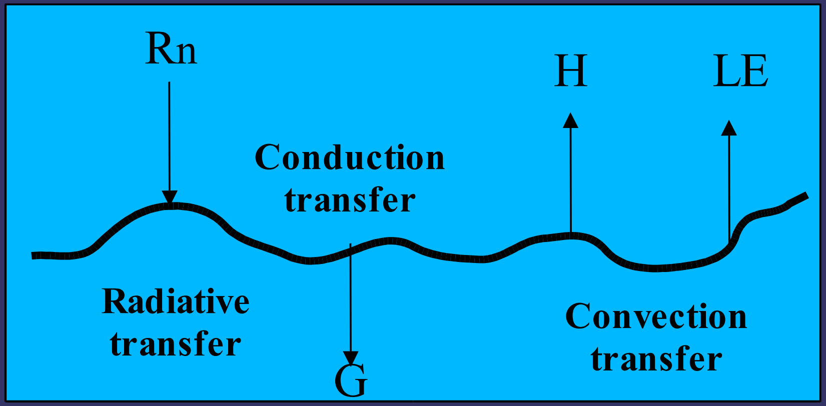
A3. Surface energy budget

$$R_N = (1-\alpha_t)R_G + \varepsilon(R_{AT} - \sigma T_S^4)$$



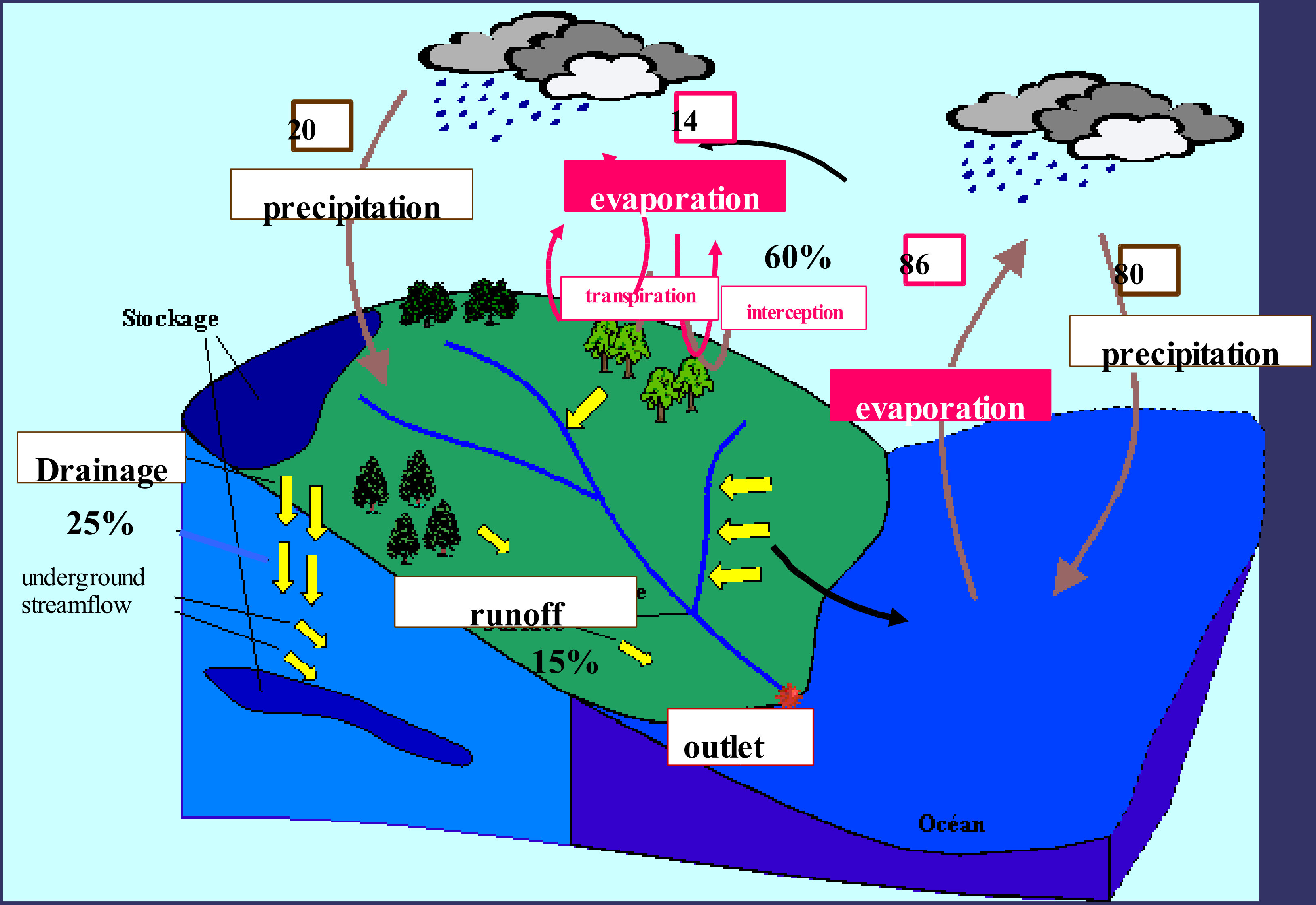
Energy absorbed by surface: $R_G - \alpha R_G + \varepsilon R_{AT}$

thermodynamics gives:



$$R_N = G + H + LE$$

A4. Water cycle



Part I. Overview of the externalized surface: theoretical background

A. Introduction to SURFEX

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B1. Initialization of physiographic fields

► PGD facility (~e923) is used to prepare physiographic fields at any scale, including subgrid orography fields at 30" resolution from GTOPO30 database

the user has to define (namelist):

- ♦ a geographic area of interest (at any place of the globe)
- ♦ a projection (between latlon, cartesian, conformal, ...)
- ♦ a grid (resolution, number of points in both directions, ...)

and to specify databases for (namelist):

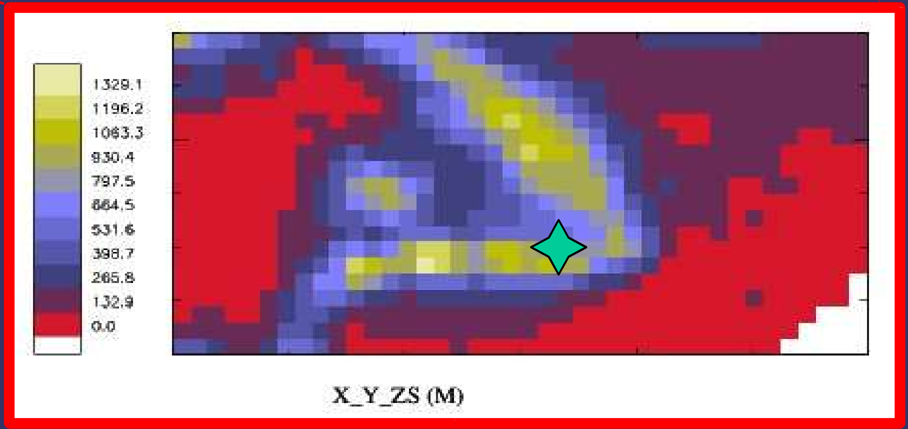
- ♦ orography
- ♦ soil texture
- ♦ vegetation

B1. Initialization of physiographic fields

- ► GTOPO30 database

Orography (m) at 1km resolution

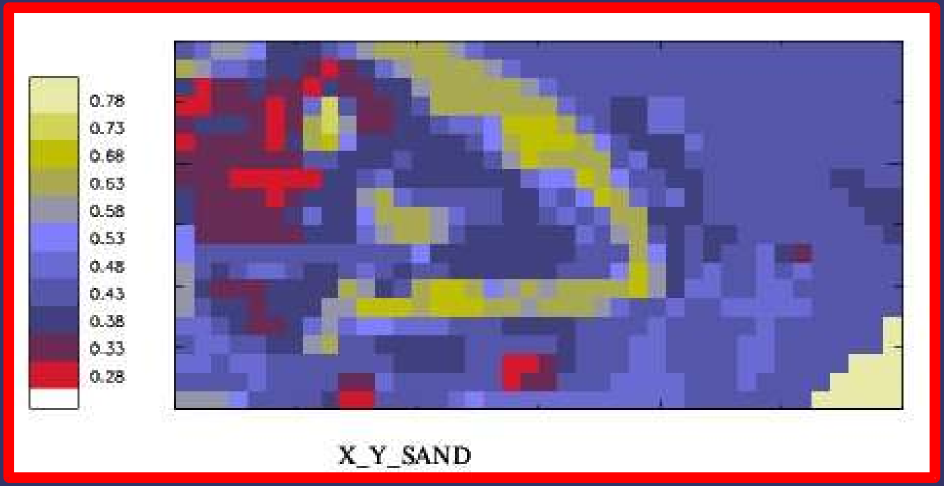
40x20 pts over Romania, ~25km mesh



B1. Initialization of physiographic fields

- ► FAO database (http://www.fao.org)

Soil texture: proportion of sand and clay at 10km resolution



B1. Initialization of physiographic fields

► ECOCLIMAP database

Global database at 1km resolution for surface parameters

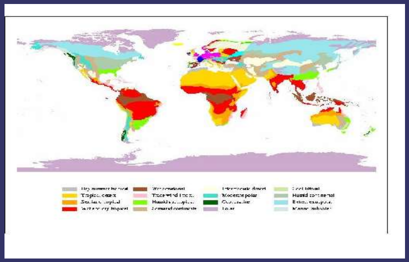
- ☻ Depending on soil
  - % sand
  - % clay
  - depth
- ☻ Depending on vegetation
  - fraction of vegetation (veg)
  - leaf area index (LAI)
  - minimal stomatal resistance (Rsmin)
  - roughness length (z0)
- ☻ Depending on soil and vegetation
  - albedo
  - emissivity

B1. Initialization of physiographic fields

► ECOCLIMAP database

DEFINING ECOSYSTEMS

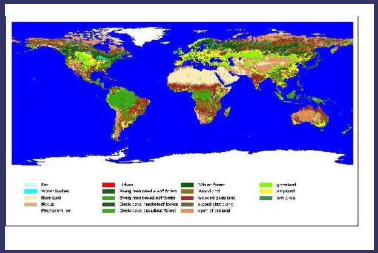
CLIMATE MAP



Koeppe et de Lond 1958

1km: 16 classes

LAND COVER MAPS



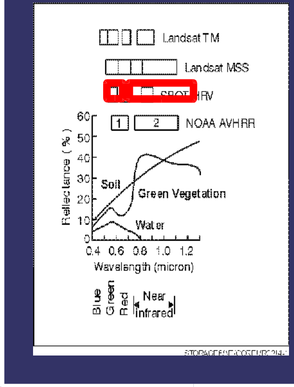
University of Maryland

1km: 15 classes

Corine land cover

« 250m »: 44 cl.

NDVI profiles: NOAA/AVHRR



215 ecosystems

B1. Initialization of physiographic fields

► ECOCLIMAP database

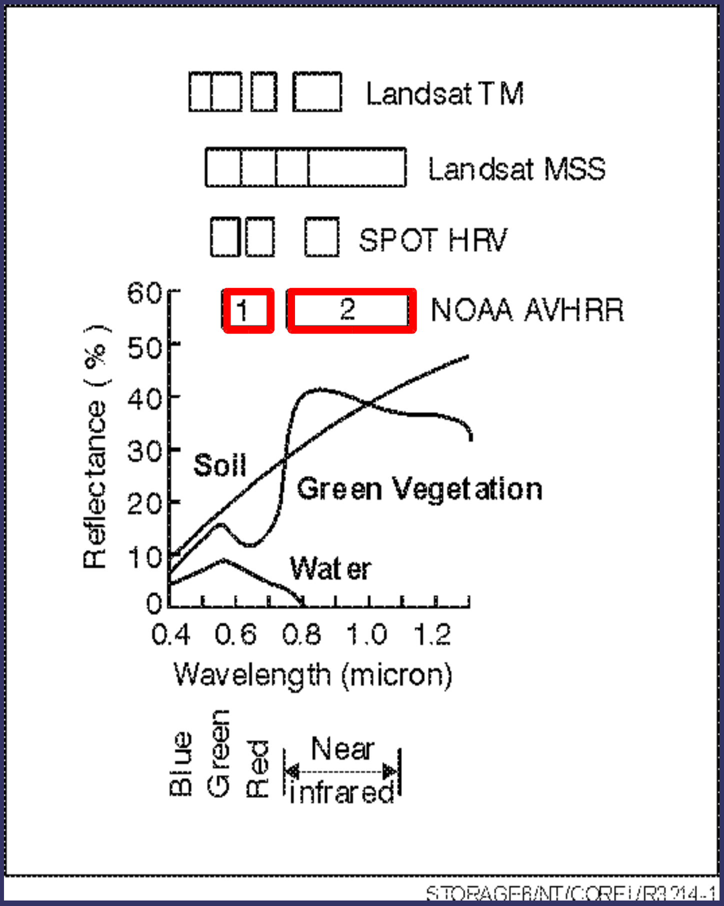
NDVI : Normalized Digital Vegetation Index

NDVI = (PIR – VIS) / (PIR + VIS)

PIR : near infra-red reflectance
[0.725 microns, 1.0 microns]

VIS : visible reflectance
[0.58 microns, 0.68 microns]

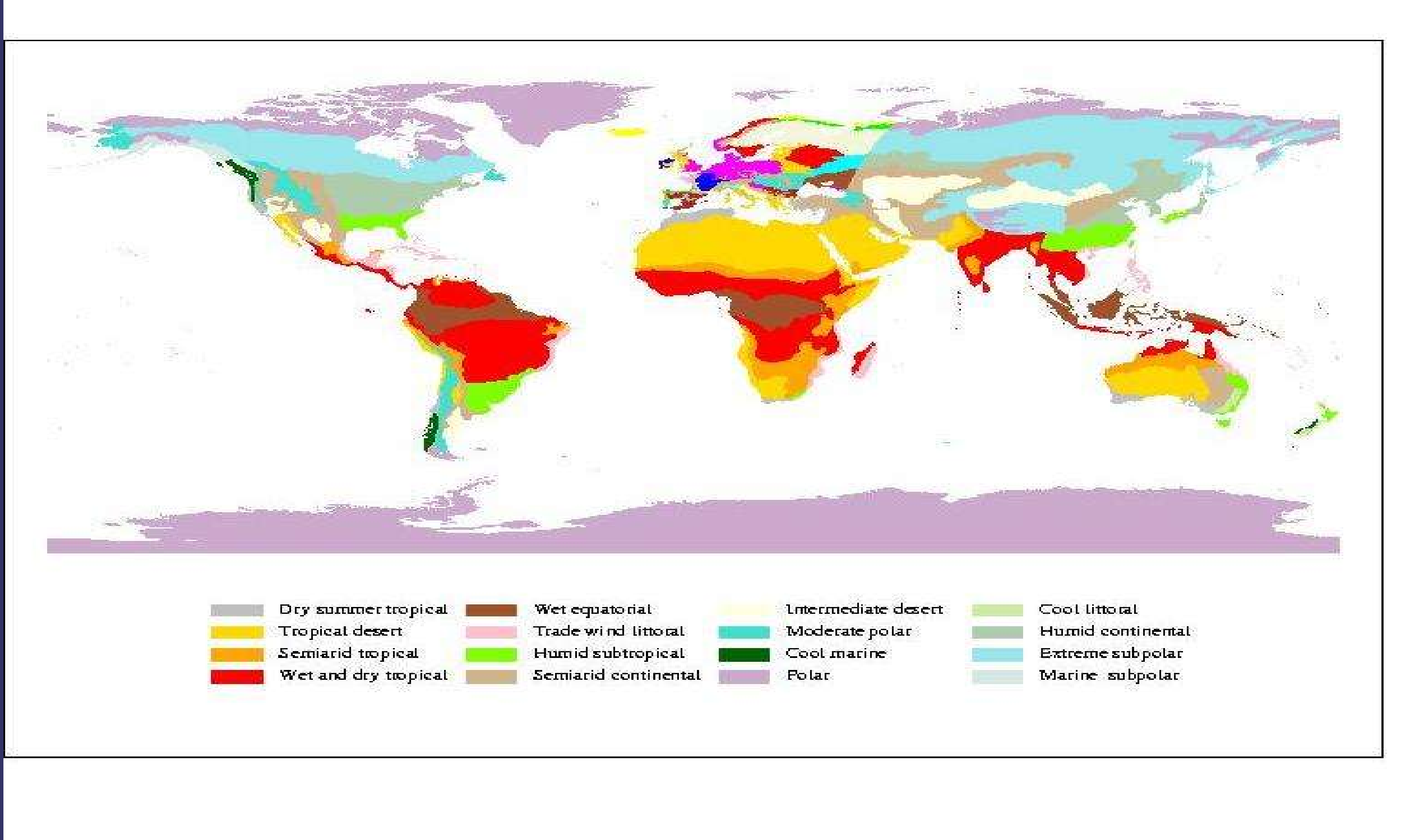
NDVI = { 0.1 ; 0.6 }



B1. Initialization of physiographic fields

► ECOCLIMAP database

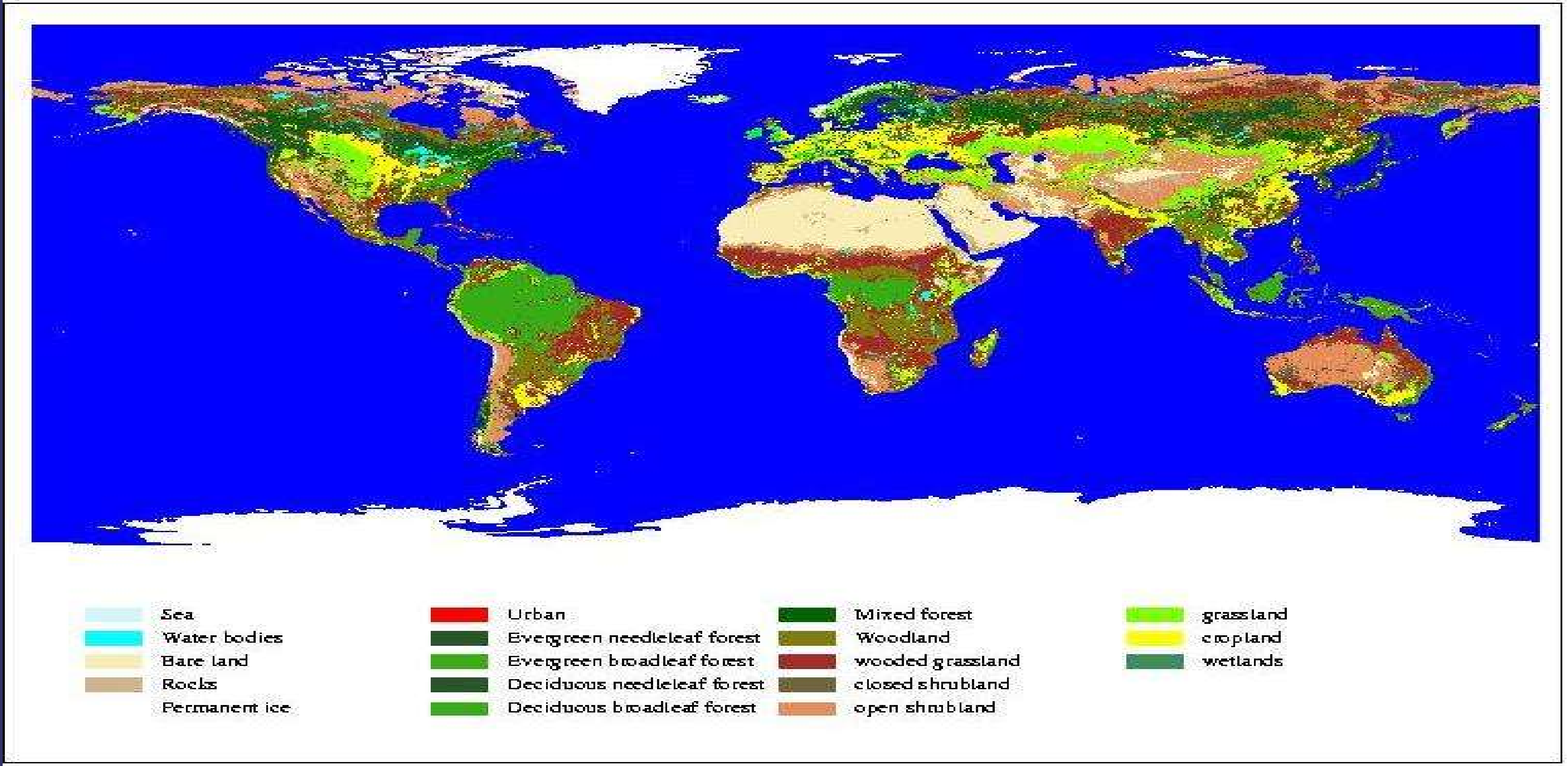
CLIMATE MAP (Koeppe et de Lond, 1958)



B1. Initialization of physiographic fields

► ECOCLIMAP database

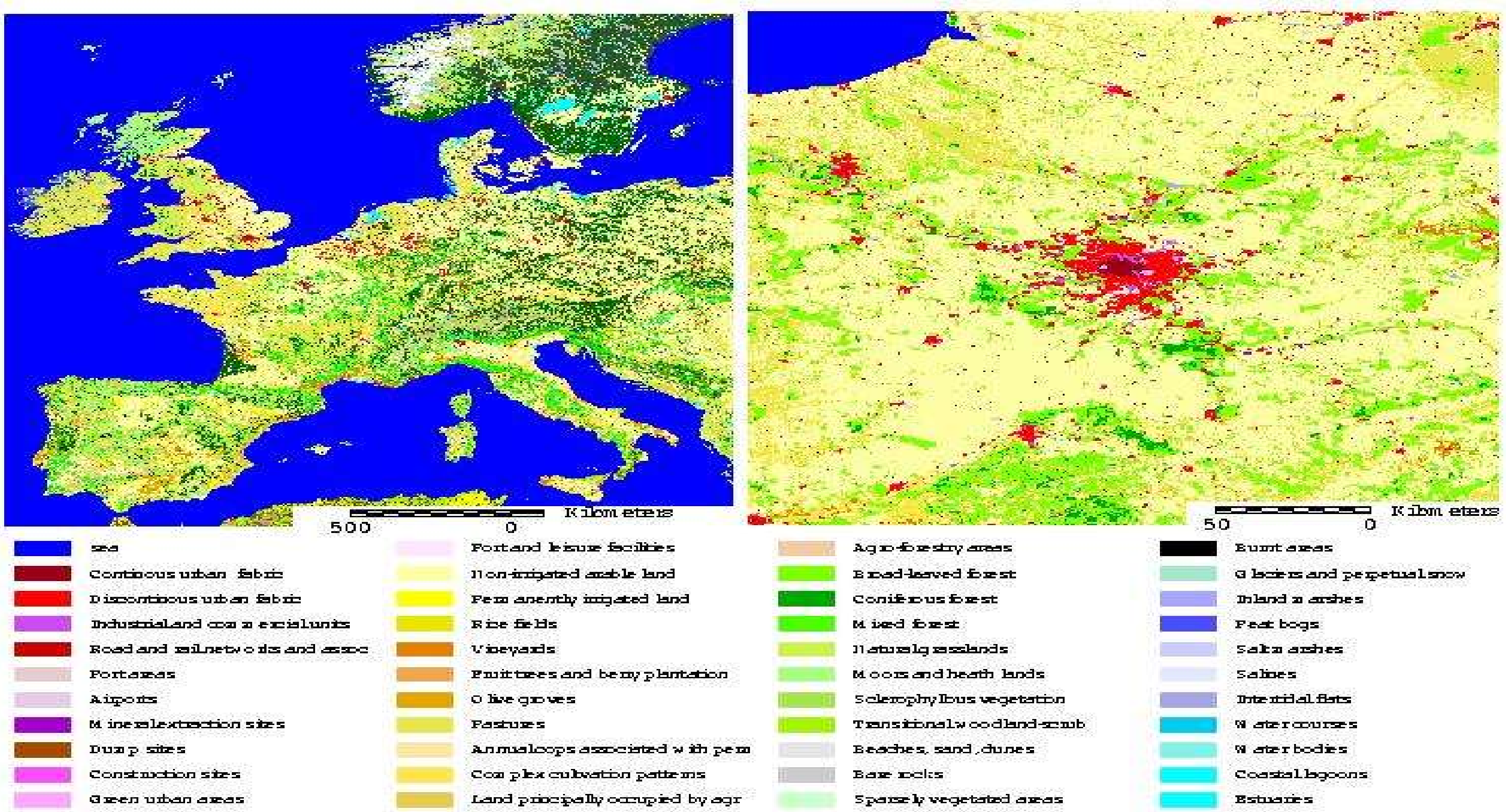
LAND COVER MAPS (university of Maryland, 1km)



B1. Initialization of physiographic fields

► ECOCLIMAP database

LAND COVER MAPS (Corine land cover, 1km)

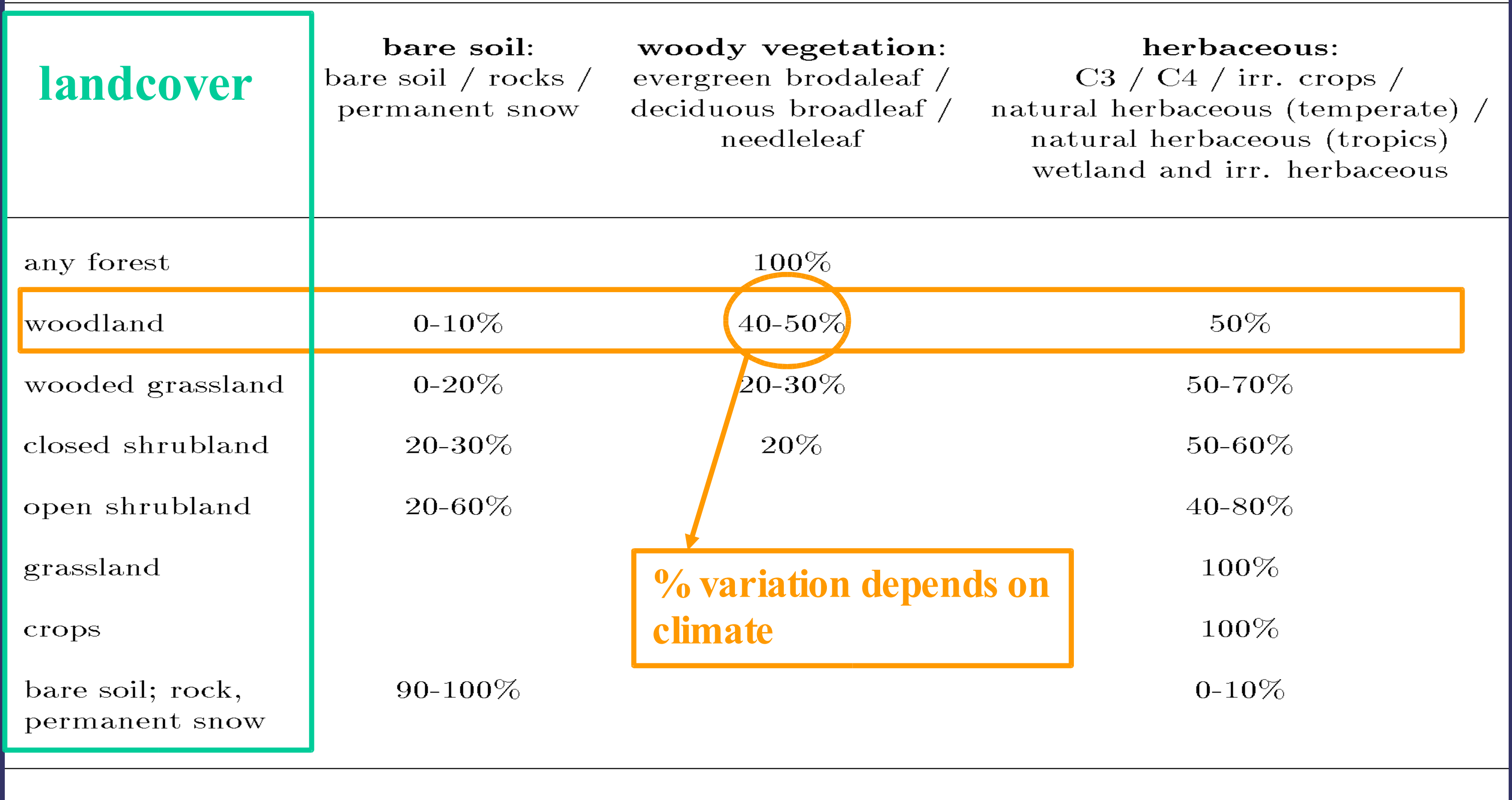


B1. Initialization of physiographic fields

► ECOCLIMAP algorithm

Each land cover is represented as a fraction of vegetation types (12 vegetation types):

fraction of woody vegetation, herbaceous vegetation and bare soil for each land cover



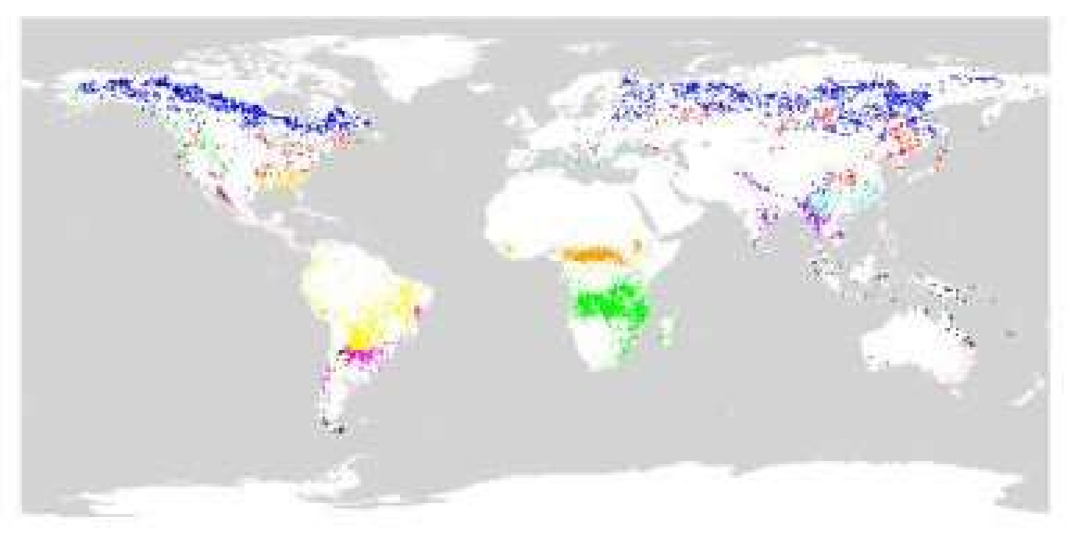
landcover	**bare soil:** bare soil / rocks / permanent snow	**woody vegetation:** evergreen brodaleaf / deciduous broadleaf / needleleaf	**herbaceous:** C3 / C4 / irr. crops / natural herbaceous (temperate) / natural herbaceous (tropics) wetland and irr. herbaceous
any forest		100%	
woodland	0-10%	40-50%	50%
wooded grassland	0-20%	20-30%	50-70%
closed shrubland	20-30%	20%	50-60%
open shrubland	20-60%		40-80%
grassland			100%
crops			100%
bare soil; rock, permanent snow	90-100%		0-10%

% variation depends on climate

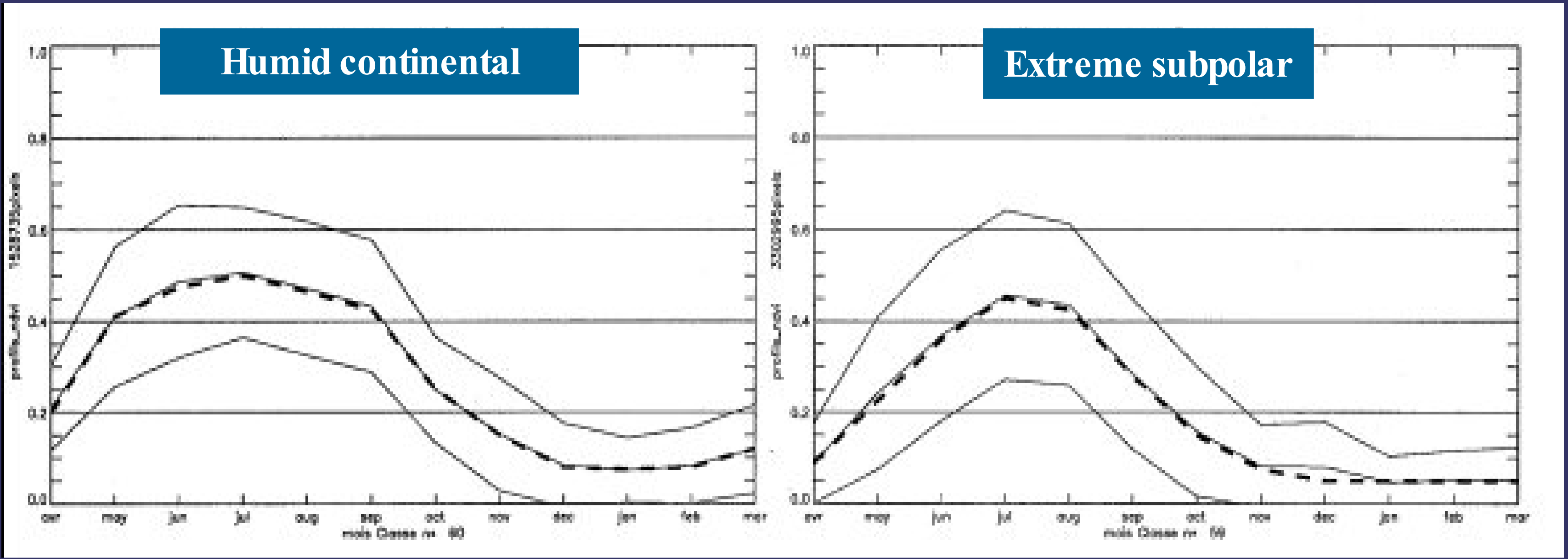
B1. Initialization of physiographic fields

► ECOCLIMAP algorithm

1. Global repartition of woodland

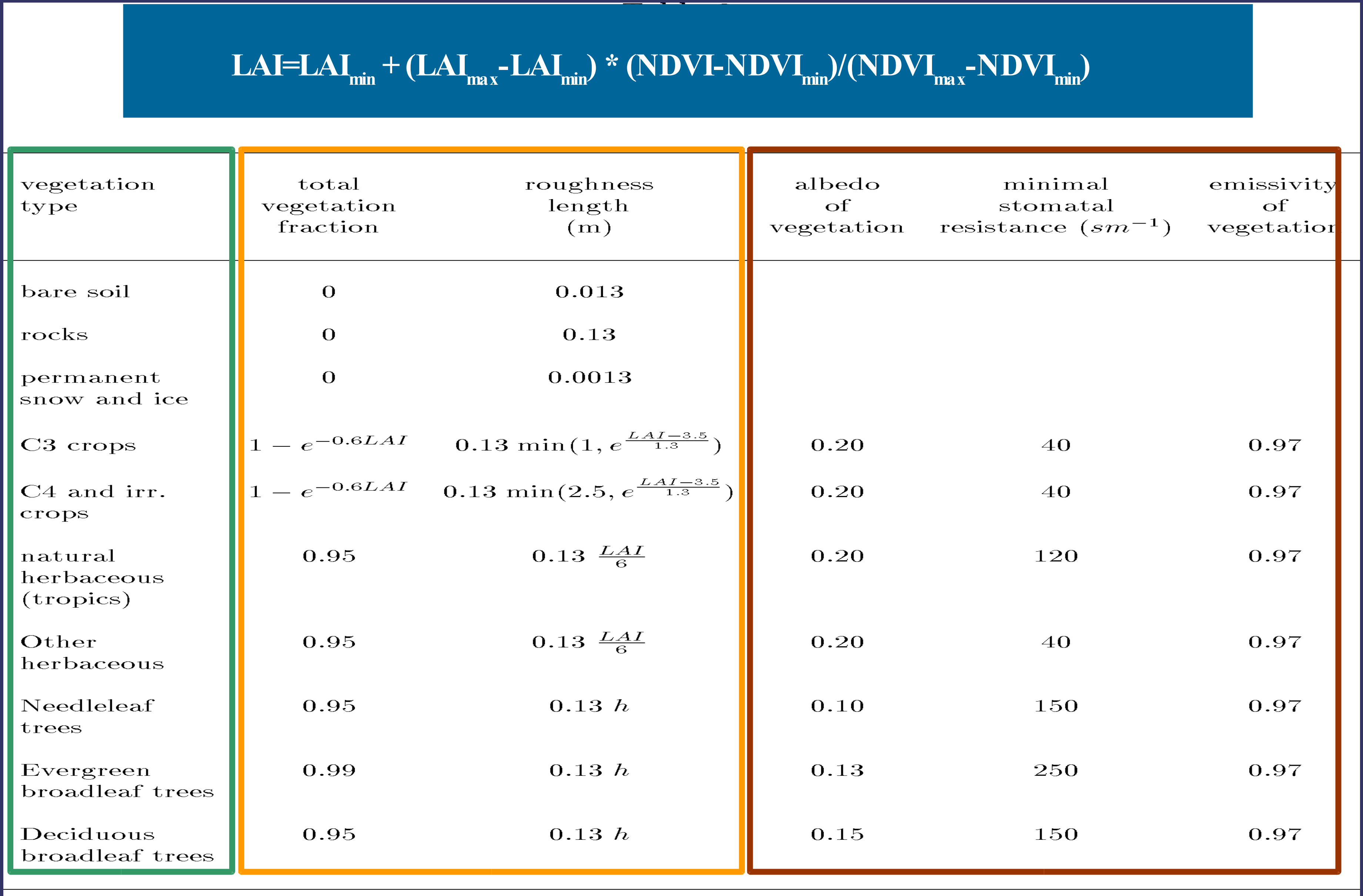


2. NDVI profiles of wooded grassland



B1. Initialization of physiographic fields

- ► ECOCLIMAP algorithm: computation of surface parameters

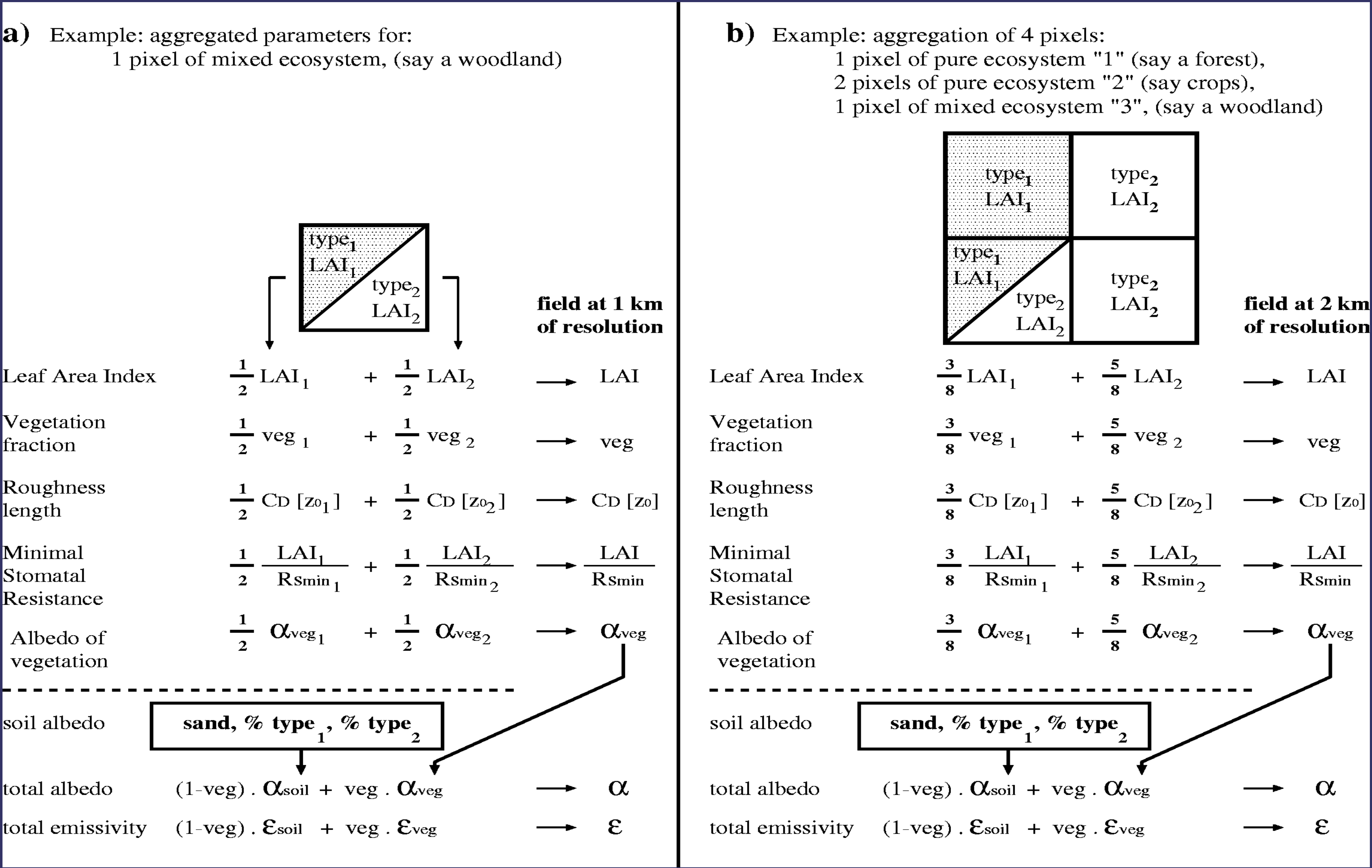


$$LAI = LAI_{min} + (LAI_{max} - LAI_{min}) * (NDVI - NDVI_{min})/(NDVI_{max} - NDVI_{min})$$

vegetation type	total vegetation fraction	roughness length (m)	albedo of vegetation	minimal stomatal resistance (sm^{-1})	emissivity of vegetation
bare soil	0	0.013			
rocks	0	0.13			
permanent snow and ice	0	0.0013			
C3 crops	$1 - e^{-0.6LAI}$	$0.13 \min(1, e^{\frac{LAI-3.5}{1.3}})$	0.20	40	0.97
C4 and irr. crops	$1 - e^{-0.6LAI}$	$0.13 \min(2.5, e^{\frac{LAI-3.5}{1.3}})$	0.20	40	0.97
natural herbaceous (tropics)	0.95	$0.13 \frac{LAI}{6}$	0.20	120	0.97
Other herbaceous	0.95	$0.13 \frac{LAI}{6}$	0.20	40	0.97
Needleleaf trees	0.95	$0.13\ h$	0.10	150	0.97
Evergreen broadleaf trees	0.99	$0.13\ h$	0.13	250	0.97
Deciduous broadleaf trees	0.95	$0.13\ h$	0.15	150	0.97

B1. Initialization of physiographic fields

► ECOCLIMAP algorithm: aggregation rules



a) Example: aggregated parameters for:
1 pixel of mixed ecosystem, (say a woodland)

field at 1 km of resolution

Leaf Area Index	$\frac{1}{2} LAI_1 + \frac{1}{2} LAI_2$	$\longrightarrow LAI$
Vegetation fraction	$\frac{1}{2} veg_1 + \frac{1}{2} veg_2$	$\longrightarrow veg$
Roughness length	$\frac{1}{2} C_D[z_{0_1}] + \frac{1}{2} C_D[z_{0_2}]$	$\longrightarrow C_D[z_0]$
Minimal Stomatal Resistance	$\frac{1}{2} \frac{LAI_1}{Rs_{min\,1}} + \frac{1}{2} \frac{LAI_2}{Rs_{min\,2}}$	$\longrightarrow \frac{LAI}{Rs_{min}}$
Albedo of vegetation	$\frac{1}{2} \alpha_{veg_1} + \frac{1}{2} \alpha_{veg_2}$	$\longrightarrow \alpha_{veg}$
soil albedo	**sand, % $type_1$, % $type_2$**	
total albedo	$(1-veg) . \alpha_{soil} + veg . \alpha_{veg}$	$\longrightarrow \alpha$
total emissivity	$(1-veg) . \varepsilon_{soil} + veg . \varepsilon_{veg}$	$\longrightarrow \varepsilon$

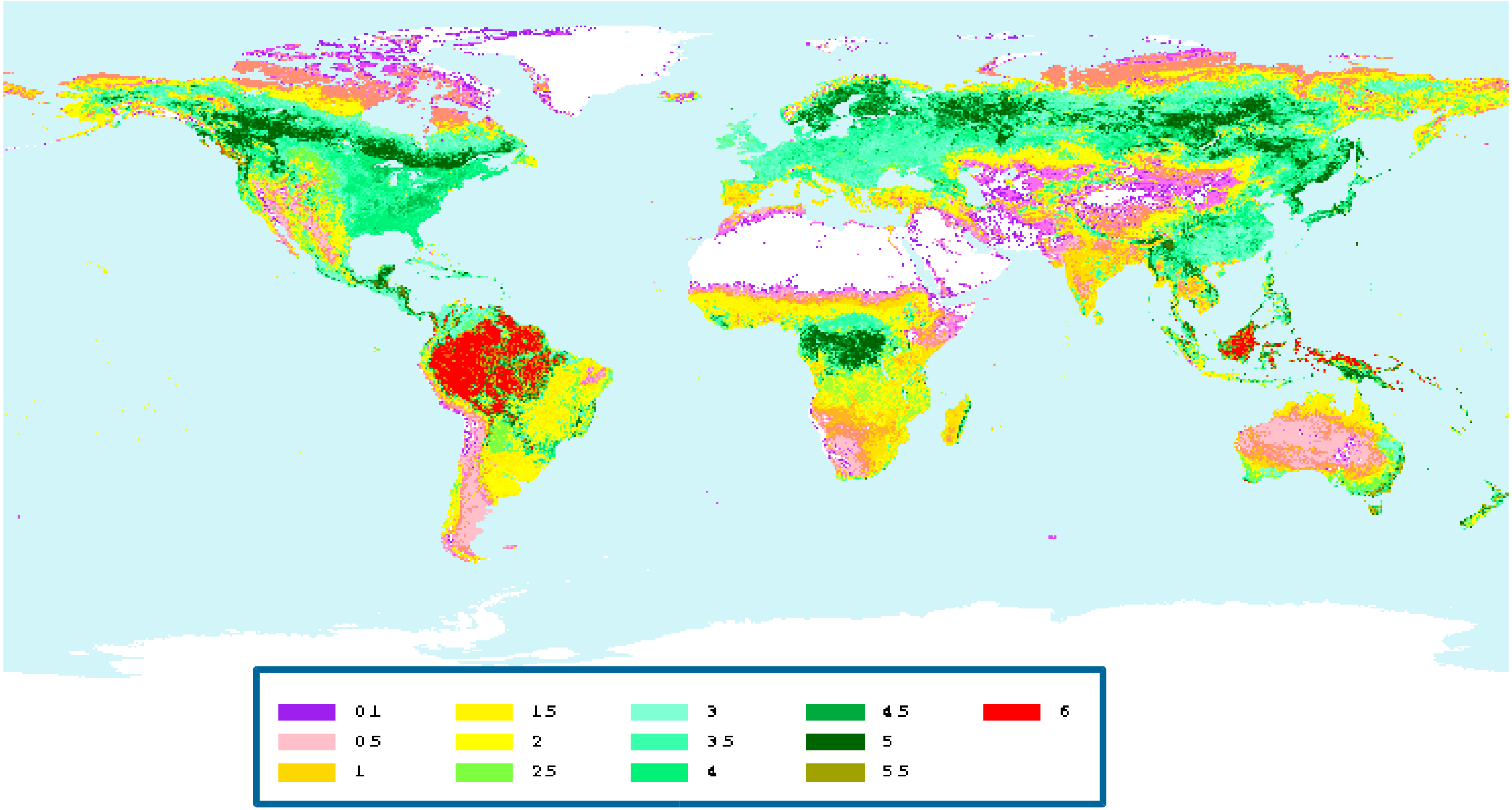
b) Example: aggregation of 4 pixels:
1 pixel of pure ecosystem "1" (say a forest),
2 pixels of pure ecosystem "2" (say crops),
1 pixel of mixed ecosystem "3", (say a woodland)

field at 2 km of resolution

Leaf Area Index	$\frac{3}{8} LAI_1 + \frac{5}{8} LAI_2$	$\longrightarrow LAI$
Vegetation fraction	$\frac{3}{8} veg_1 + \frac{5}{8} veg_2$	$\longrightarrow veg$
Roughness length	$\frac{3}{8} C_D[z_{0_1}] + \frac{5}{8} C_D[z_{0_2}]$	$\longrightarrow C_D[z_0]$
Minimal Stomatal Resistance	$\frac{3}{8} \frac{LAI_1}{Rs_{min\,1}} + \frac{5}{8} \frac{LAI_2}{Rs_{min\,2}}$	$\longrightarrow \frac{LAI}{Rs_{min}}$
Albedo of vegetation	$\frac{3}{8} \alpha_{veg_1} + \frac{5}{8} \alpha_{veg_2}$	$\longrightarrow \alpha_{veg}$
soil albedo	**sand, % $type_1$, % $type_2$**	
total albedo	$(1-veg) . \alpha_{soil} + veg . \alpha_{veg}$	$\longrightarrow \alpha$
total emissivity	$(1-veg) . \varepsilon_{soil} + veg . \varepsilon_{veg}$	$\longrightarrow \varepsilon$

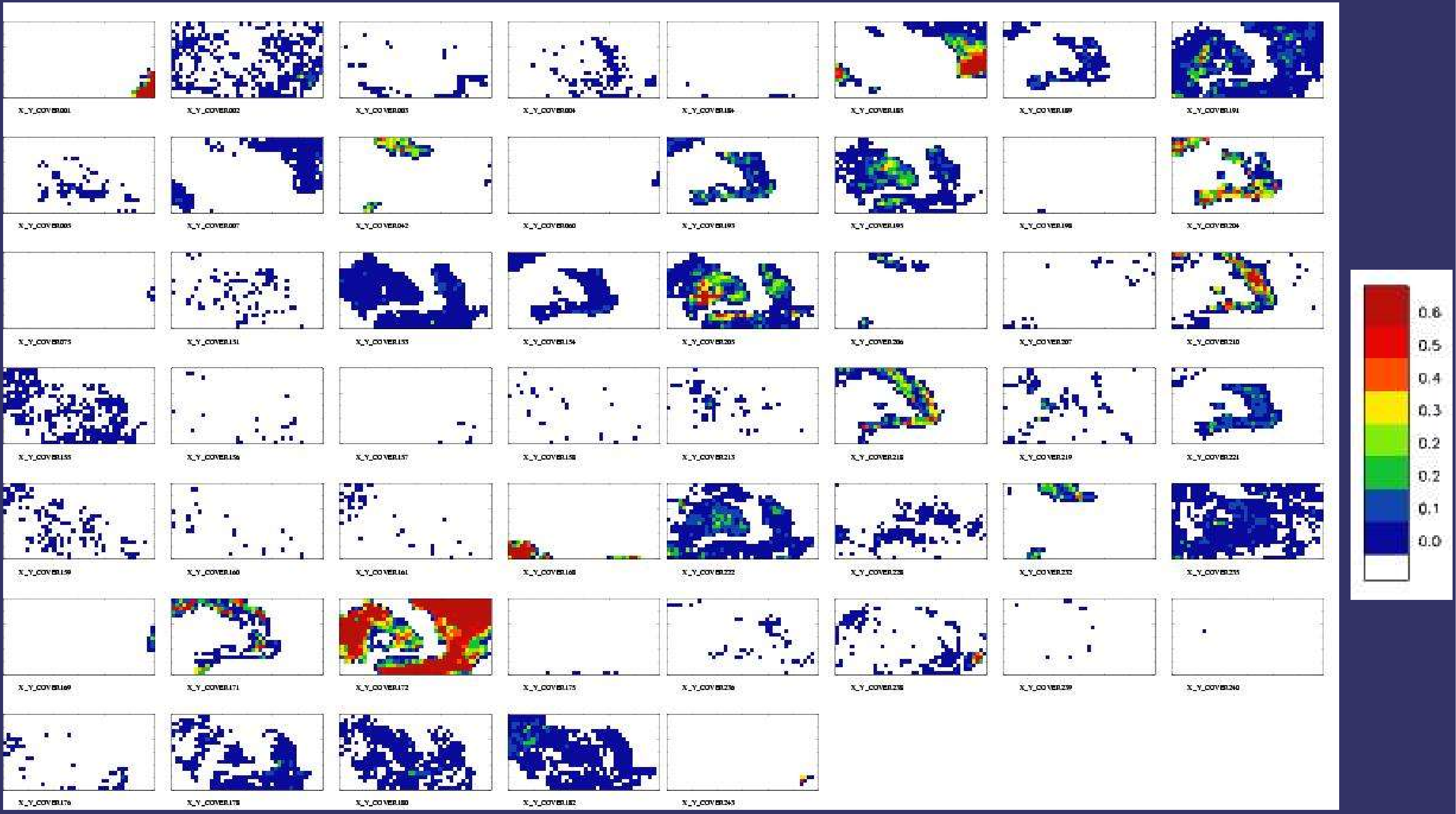
B1. Initialization of physiographic fields

► ECOCLIMAP results: Leaf Area Index for July



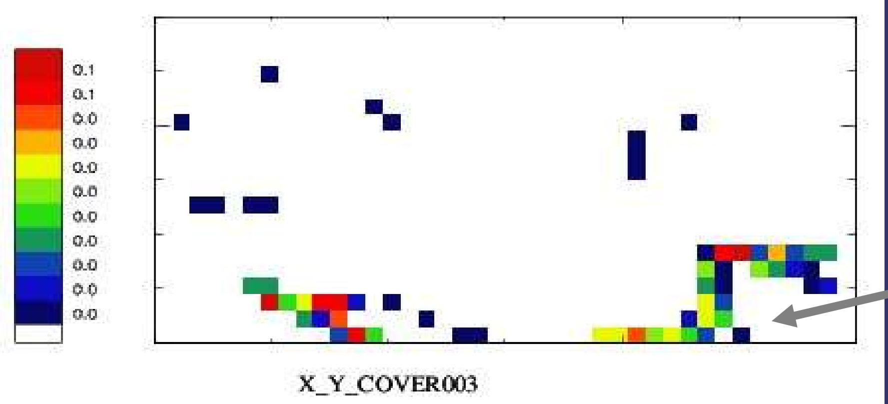
B1. Initialization of physiographic fields

► ECOCLIMAP results: example over Romania (53 covers)



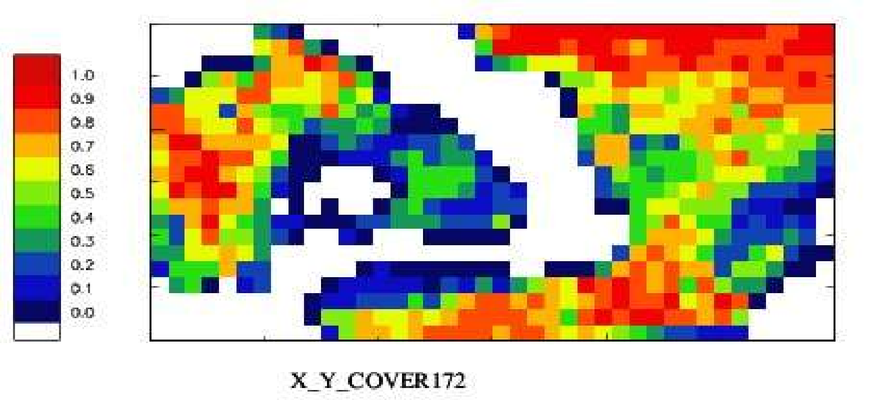
B1. Initialization of physiographic fields

► ECOCLIMAP results: 3 particular covers

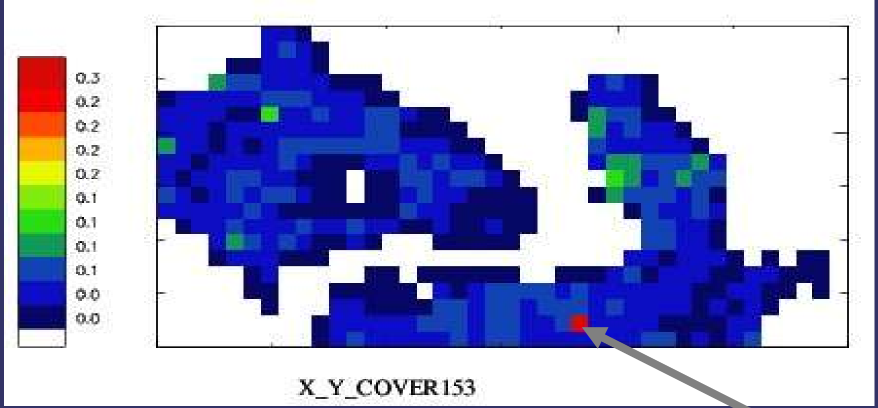


Rivers

Duna river



Central Europe crops



Temperate suburban

Bucarest

B2. Initialization of prognostic fields

► PREP facility (~e927) is used to initialize prognostic variables from different atmospheric models like:

ECMWF, ARPEGE, ALADIN, MESO-NH, MOCAGE

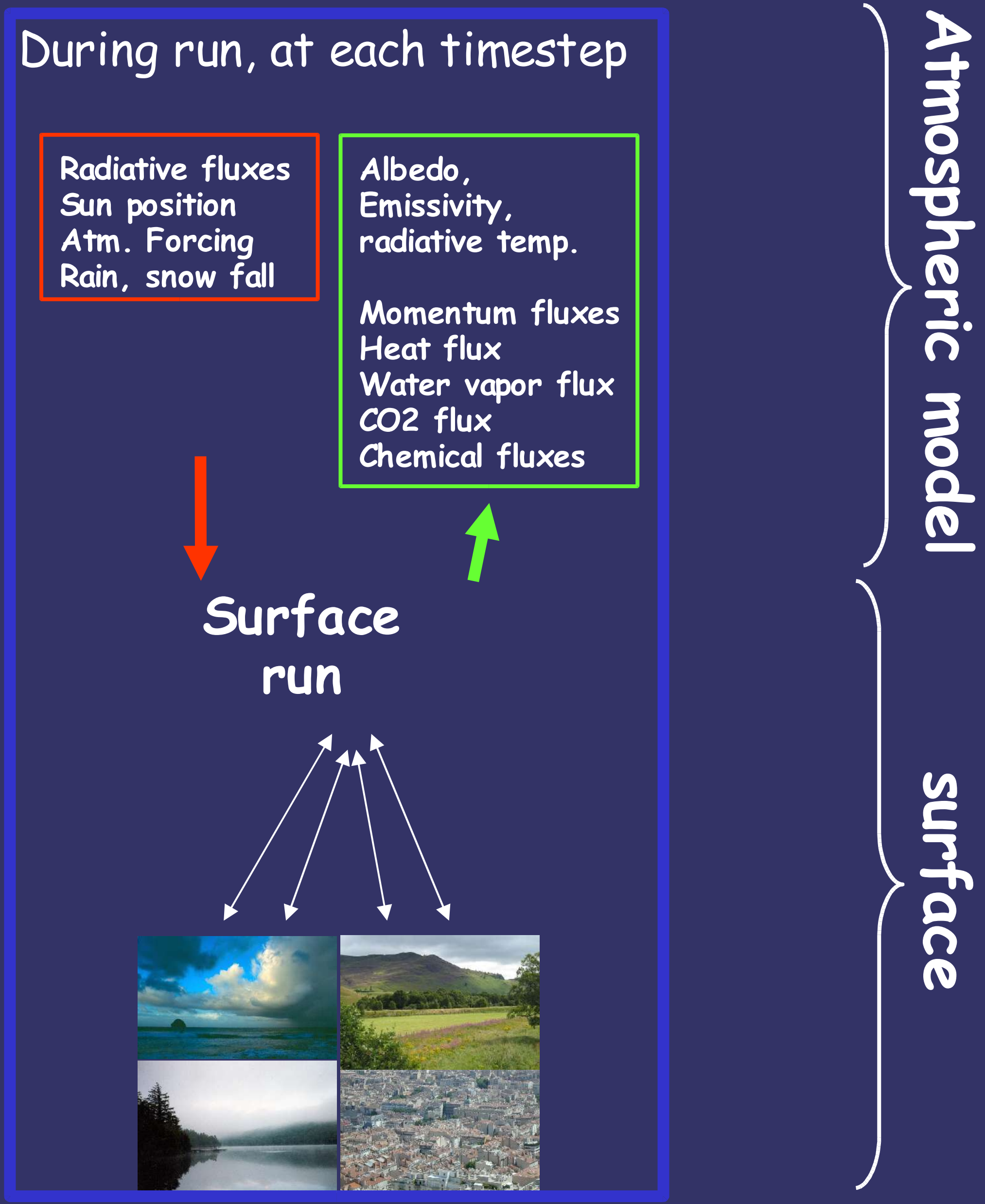
usually following variables need to be set up:

☺ vertical profiles for temperature, liquid water and ice (nature)
☺ temperatures of road, wall and roof (urban areas)
☺ sst and water temperature for respectively seas and lakes
☺ interception water content
☺ snow water equivalent and other snow prognostic variable (depending on the snow scheme)

Fields computed with PGD will also be written in file generated by PREP application.

B3. Running surface schemes

-



During run, at each timestep

Radiative fluxes
Sun position
Atm. Forcing
Rain, snow fall

Albedo,
Emissivity,
radiative temp.

Momentum fluxes
Heat flux
Water vapor flux
CO2 flux
Chemical fluxes

Surface run

Part I. Overview of the externalized surface: theoretical background

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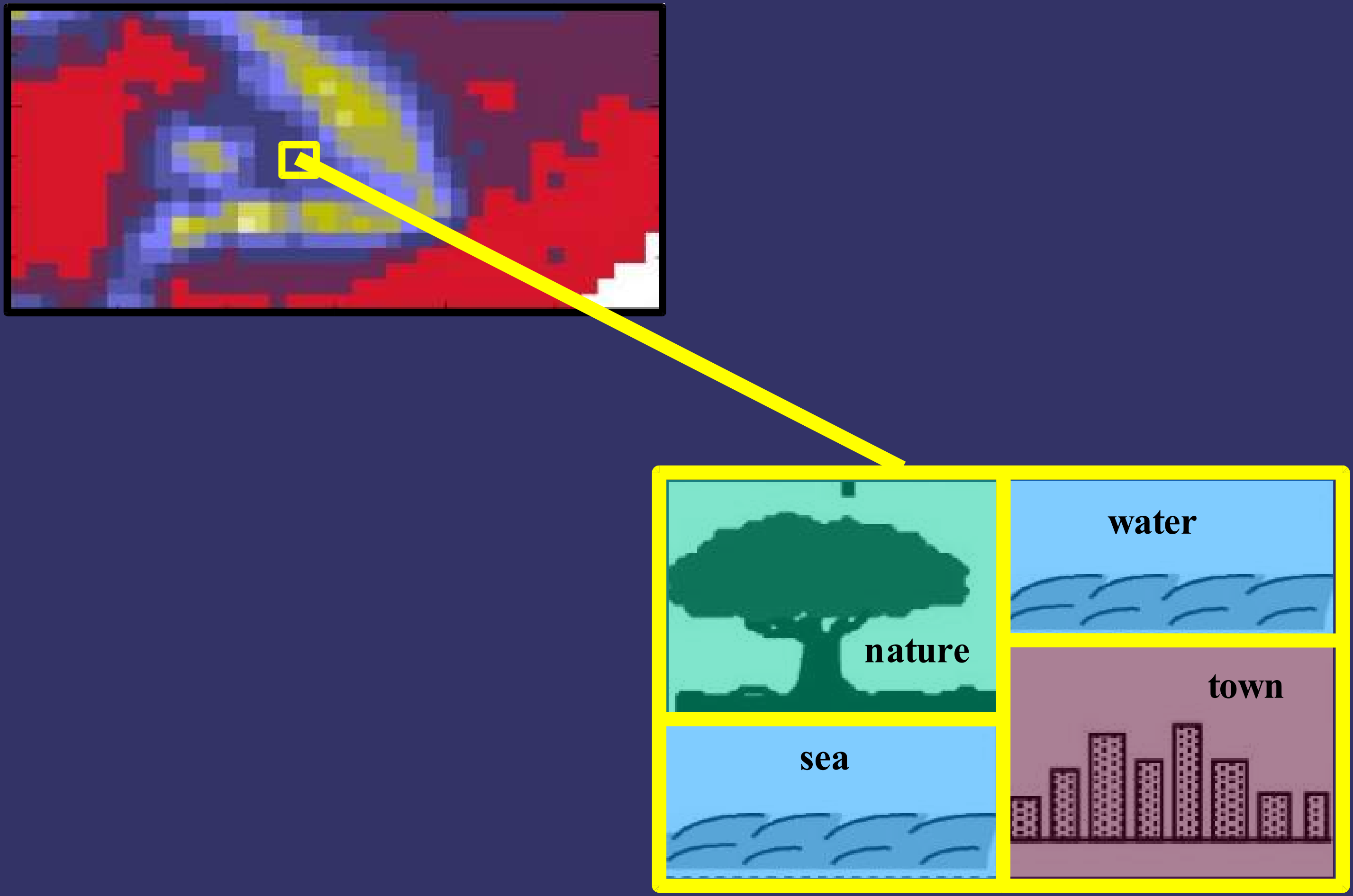
C. Princip of SURFEX

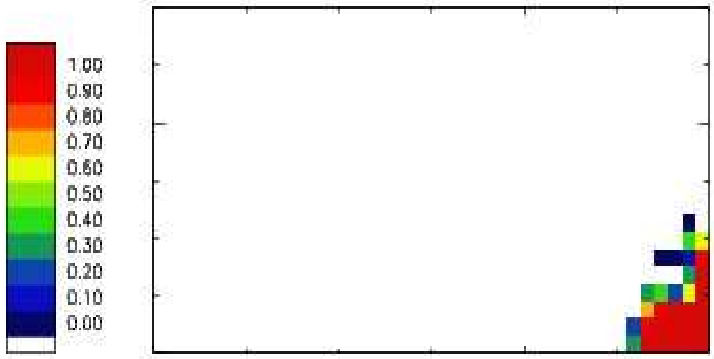
C1. SURFEX setup

- **tiling** is one important feature of the externalized surface: each grid cell is divided into 4 elementary units according to the fraction of covers in the grid cell:

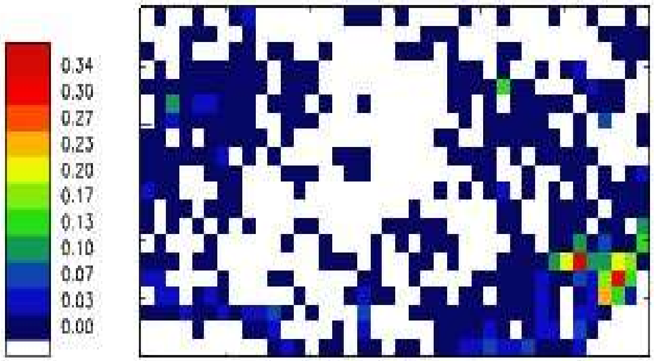


C1. SURFEX setup

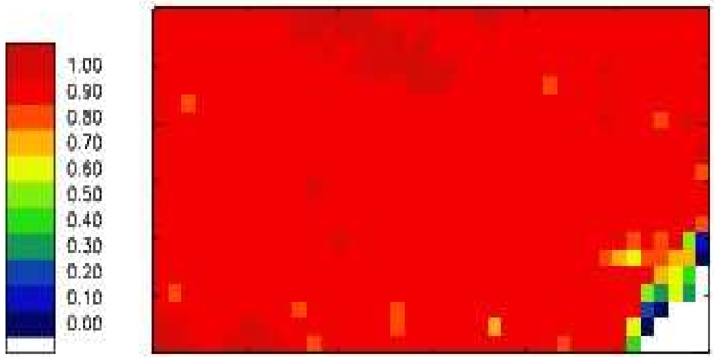
► **tiling** : example



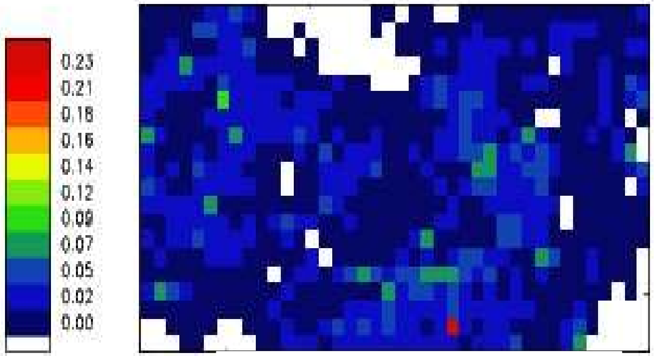
Fraction of sea



Fraction of water



Fraction of nature



Fraction of town

C1. SURFEX setup

- second level of **tiling** for vegetation: natural areas of each grid cell may be divided into several peaces called **patches**.

1: bare ground
2: rocks
3: permanent snow
4: deciduous forest
5: conifer forest
6: mixt forest
7: C3 crops
8: C4 crops
9: irrigated crops
10: woodland
11: tropical grassland
12: garden and parks

Tile nature

C1. SURFEX setup

► initialization of **masks**.

In order to optimize physical computations, a mask is associated to each tile (each patch as well if more than one patch has been defined) and the physical parameterizations are performed on physical points only (town-tile is treated only with the town scheme).

The size of the masks are computed by counting the number of grid cells which have a non-zero fraction of the tile in the domain of interest.

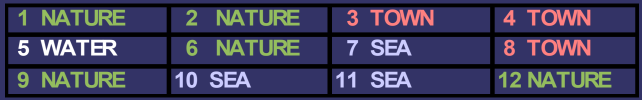
The definition of the masks are based on fortran routines PACK and UNPACK:

C1. SURFEX setup

► initialization of **masks**: example

Particular case where each grid box is represented with only one tile (pure pixel, while in reality each tile may be present in the box)

The grid is composed of 12 grid cells organized as follows:



1 NATURE	2 NATURE	3 TOWN	4 TOWN
5 WATER	6 NATURE	7 SEA	8 TOWN
9 NATURE	10 SEA	11 SEA	12 NATURE

In this case the fraction of each tile is XNATURE = 5/12, XTOWN = 3/12, XSEA = 3/12 and XWATER = 1/12 and the dimensions of the masks are respectively 5, 3, 3 and 1

C1. SURFEX setup

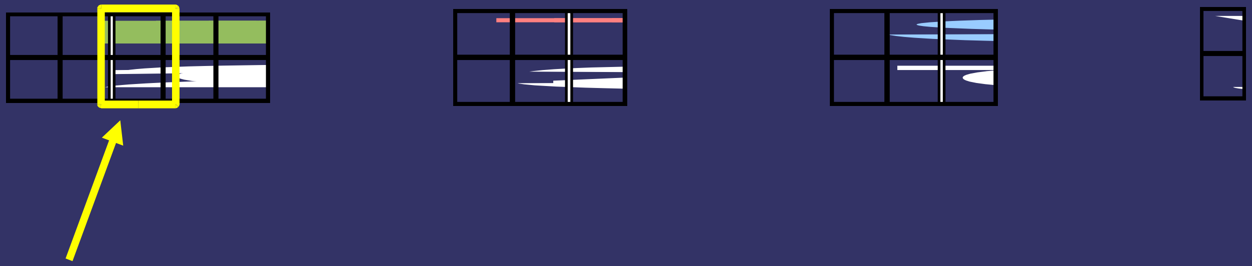
- initialization of **masks**: example

Once the fraction and the size of the mask of each tile is computed, it becomes possible to pack the variables over each tile to deduce effective mask (1D vector):

repartition of each tile over the grid

associated mask

(1, 2, 6, 9, 12)   (3, 4, 8)   (7, 10, 11)   (5)

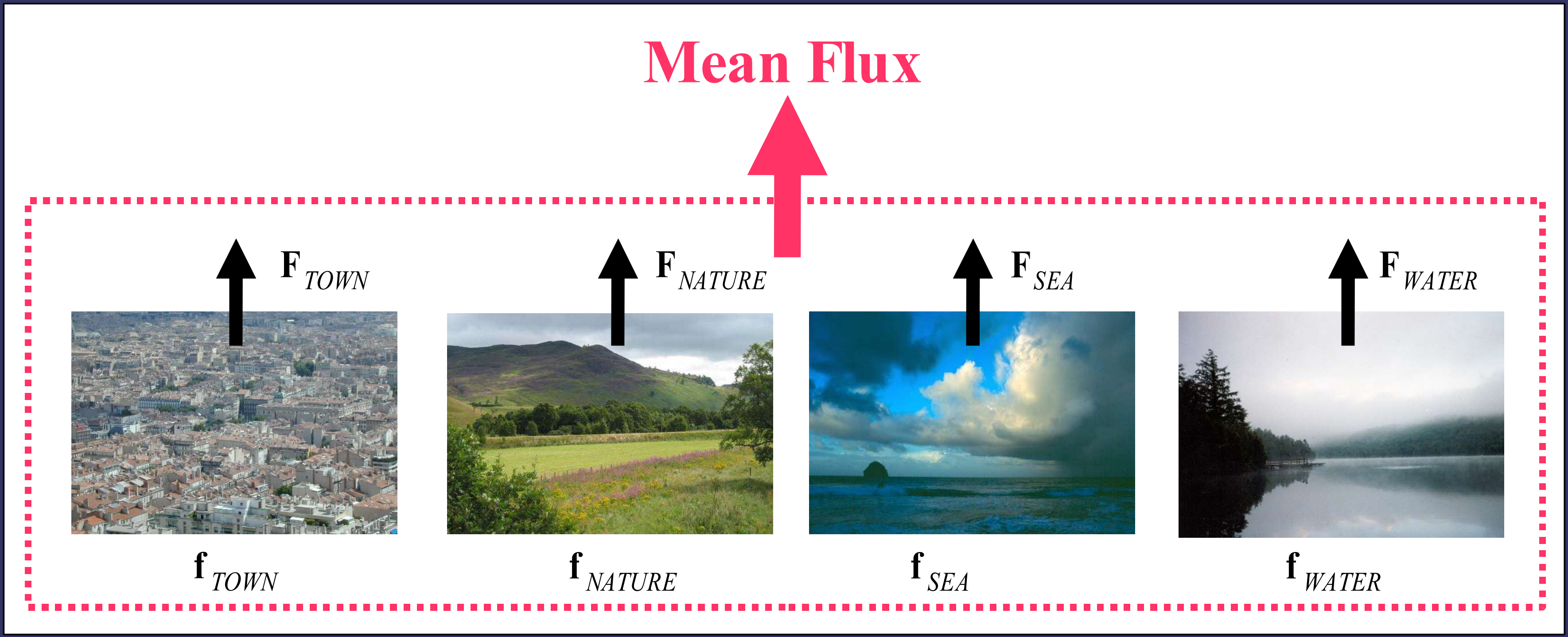


XP_NATURE (3) = X(NATURE_MASK(3)) = X(6)

C1. SURFEX setup

► princip of fluxes aggregation:

once all masks have been set up, physical computations can be done over each of them:



C1. SURFEX setup

► initialization of data from cover fields

information from PGD file is read and then for each cover
(1 to 255) some parameters are initialized like for example:

fractions of sea, nature, town and lakes

temporal cycle of LAI
fraction, root and ground depth of each vegetation type

albedo, emissivity, heat capacities, ... of artificial areas

► prognostic variables are read from initial file (PREP)

C2. I/O

- I/O belong to the model that calls SURFEX. Reading and writing orders are done using the same generic subroutine, called respectively read_surf and write_surf.

- According to the atmospheric model (AROME or Meso-NH), different subroutines are then called:

read_surfxx_mnh	write_surf_mnh	meso-nh
read_surfxx_aro	write_surfxx_aro	arome
read_surfxx_ol	write_surfxx_ol	off-line
read_surfxx_asc	write_surfxx_asc	off-line

xx is the type of the variable to be read or written

- reading and writing orders are distributed over processors

- necessary link with I/O library

C3. Organization of physical computations

- ► ISBA : Interaction between Soil, Biosphere and Atmosphere

there are 2 main options to treat the transfer of water and heat in the soil:

- Force restore method (Noilhan-Planton 1989):

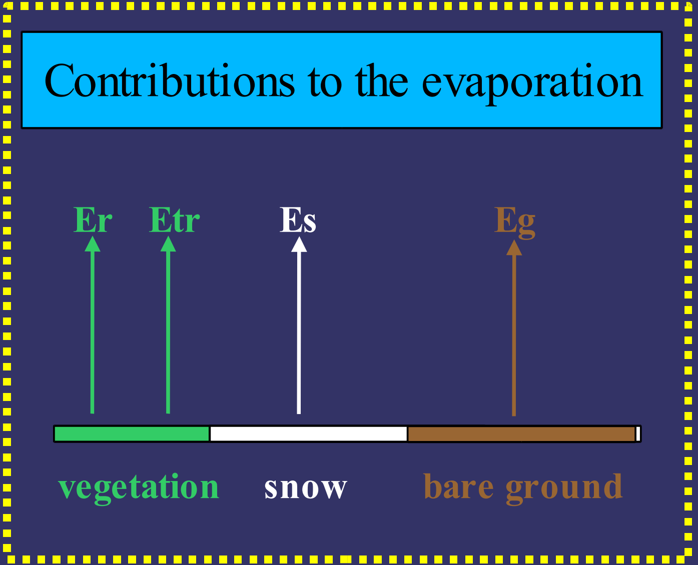
    2 or 3 layers for temperature, liquid water and ice

- Diffusion method (Boone 1999):

    n-layers for temperature, liquid water and ice

C3. Organization of physical computations

- ISBA : Interaction between Soil, Biosphere and Atmosphere



Contributions to the evaporation

Er

Etr

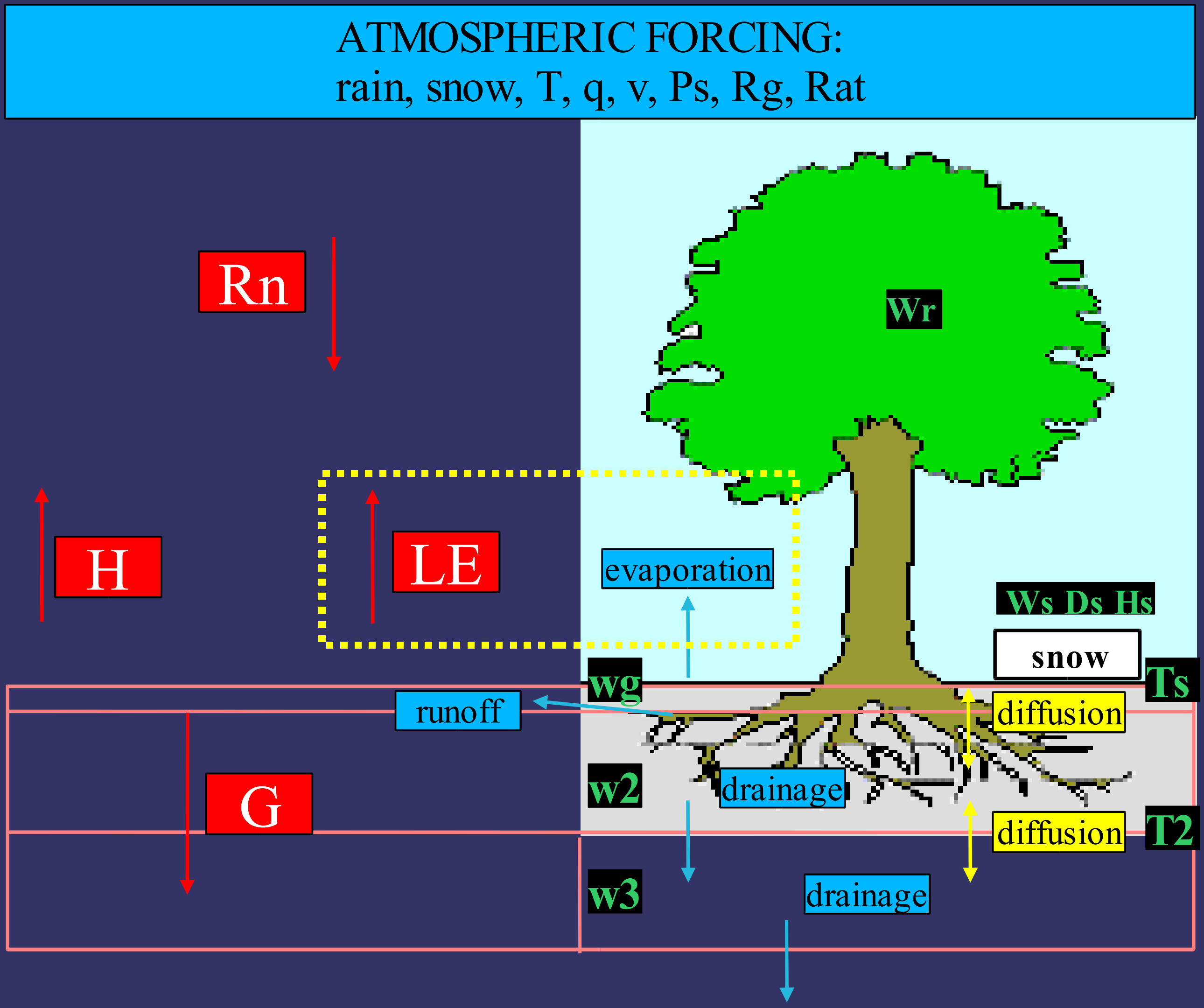
Es

Eg

vegetation

snow

bare ground



ATMOSPHERIC FORCING:
rain, snow, T, q, v, Ps, Rg, Rat

Rn

H

LE

G

Wr

evaporation

Ws Ds Hs

snow

Ts

wg

runoff

diffusion

w2

drainage

diffusion

T2

w3

drainage

C3. Organization of physical computations

► ISBA : basic equations

Temperature:

$$\frac{\partial T_s}{\partial t} = C_T (G) - \frac{2\pi}{\tau} (T_s - T_2) \qquad (1)$$

$$\frac{\partial T_2}{\partial t} = \frac{1}{\tau} (T_s - T_2) \qquad (2)$$

CT thermal capacity for soil-vegetation-snow

τ day duration

G ground heat flux

without ice :

$$C_V = 2\,.10^{-5} [kg\,.m^2.J^{-1}]$$

$$\frac{1}{C_T} = \frac{1-veg}{C_G} + \frac{veg}{C_V}$$

$$C_G = C_{Gsat} \left(\frac{w_{sat}}{w_2} \right)^{b/2\ln(10)}$$

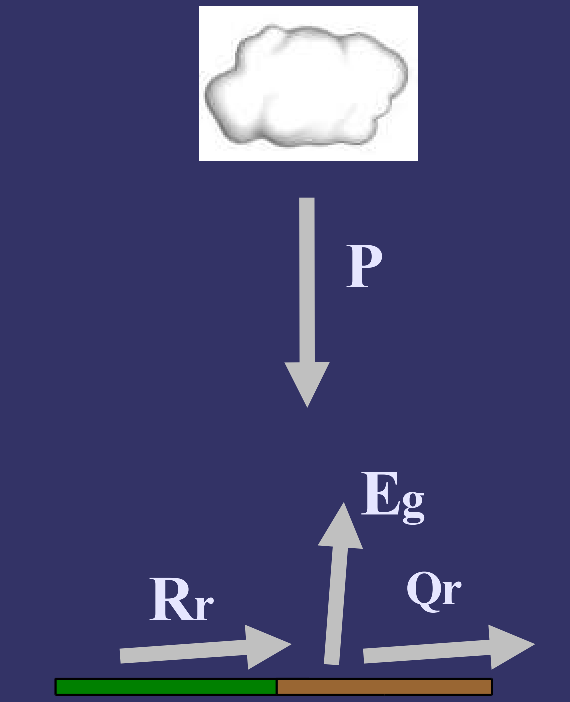
C3. Organization of physical computations

- ► ISBA : basic equations

Water content:

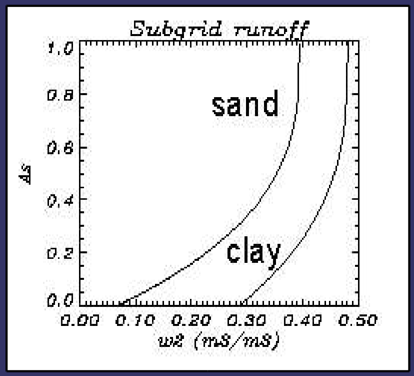
$$\frac{\partial w_g}{\partial t} = \frac{C_1}{\rho_w d_1}\left(P_g - E_g\right) - \frac{C_2}{\tau}\left(w_g - w_{geq}\right) \qquad (3)$$

$$P_g = \left(1 - veg\right)P + R_r - Q_r$$



P	total precipitation rate
Eg	bare ground evaporation
wgeq	balance water content (gravity/capillarity)
Rr	interception runoff
Qr	surface runoff

surface runoff Qr occurs over saturated area



C3. Organization of physical computations

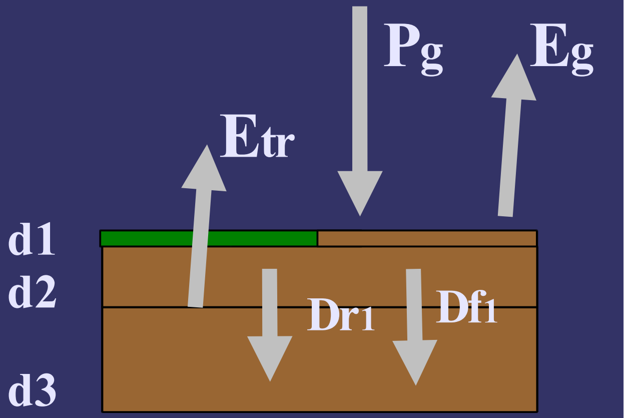
- ISBA : basic equations

Water content:

$$\frac{\partial w_2}{\partial t} = \frac{1}{\rho_w d_2}\left(P_g - E_g - E_{tr}\right) - D_{r1} - D_{f1} \qquad (4)$$

E_{tr}	evapotranspiration of plant
D_{r1}	root layer drainage
D_{f1}	diffusion between w2 and w3 layers

$$D_{f1} = \frac{C_4}{\tau}\left(w_2 - w_3\right)$$

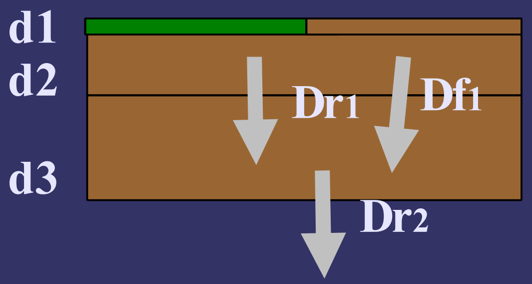


C3. Organization of physical computations

- ► ISBA : basic equations

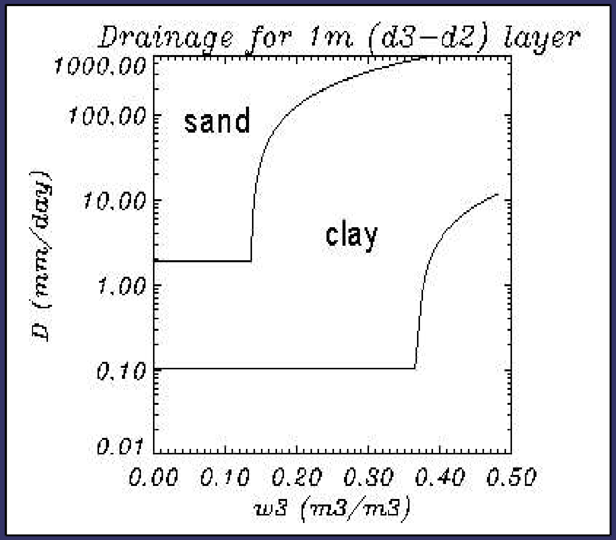
Water content:

$$\frac{\partial w_3}{\partial t} = \frac{d_2}{d_3 - d_2}\left(D_{r1} + D_{f1}\right) - D_{r2} \qquad (5)$$



Dr2: deep layer drainage

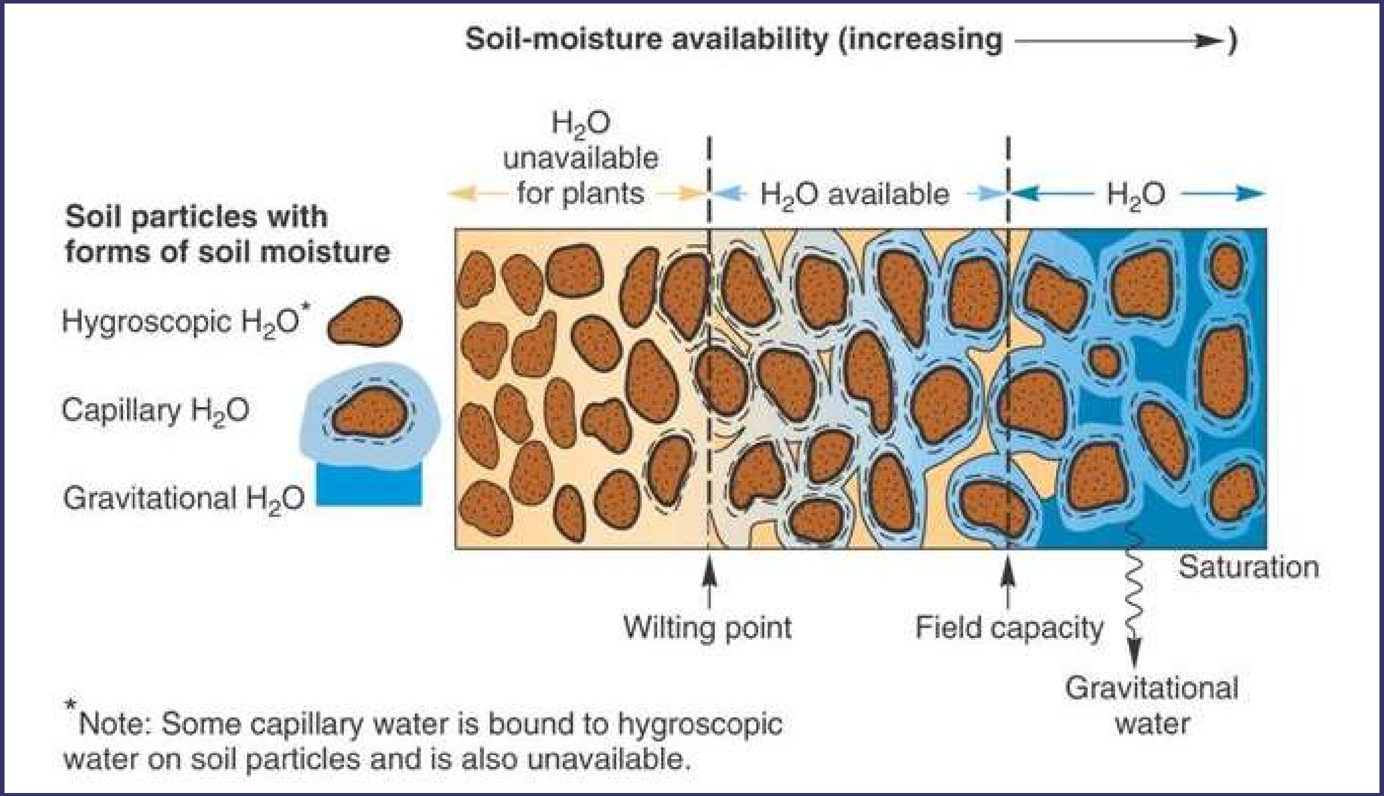
$$D_r = -\frac{C_3}{\tau}\frac{1}{d}\max\left[e_b, \left(w - w_{fc}\right)\right]$$



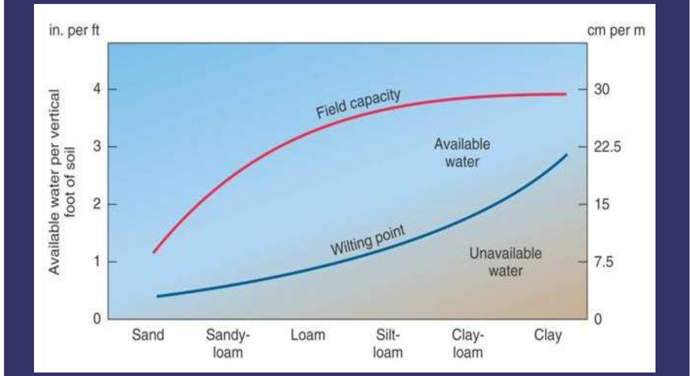
C3. Organization of physical computations

► ISBA : basic equations

Available water:



*Note: Some capillary water is bound to hygroscopic water on soil particles and is also unavailable.

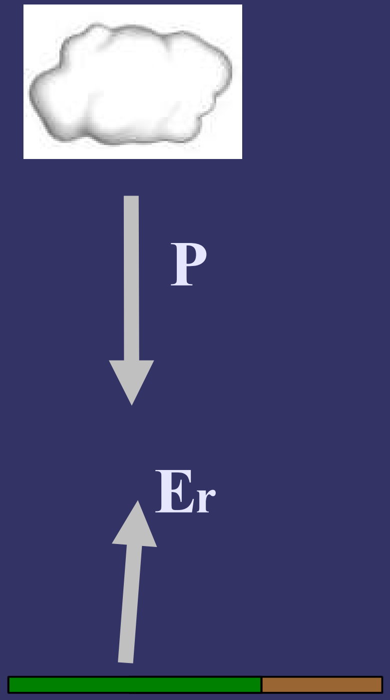


C3. Organization of physical computations

- ISBA : basic equations

Interception reservoir:

$$\frac{\partial W_r}{\partial t} = veg(P) - E_r \qquad (6)$$



C3. Organization of physical computations

- ► ISBA : basic equations

summary:

$$\frac{\partial T_s}{\partial t} = C_T (G) - \frac{2\pi}{\tau}(T_s - T_2)$$

$$\frac{\partial T_2}{\partial t} = \frac{1}{\tau}(T_s - T_2)$$

$$\frac{\partial w_g}{\partial t} = \frac{C_1}{\rho_w d_1}(P_g - E_g) - \frac{C_2}{\tau}(w_g - w_{geq})$$

$$\frac{\partial w_2}{\partial t} = \frac{1}{\rho_w d_2}(P_g - E_g - E_{tr}) - D_{r1} - D_{f1}$$

$$\frac{\partial w_3}{\partial t} = \frac{d_2}{d_3 - d_2}(D_{r1} + D_{f1}) - D_{r2}$$

$$\frac{\partial W_r}{\partial t} = veg(P) - E_r$$

🟢 fct of precipitation and runoff

🟣 fct of water contents, soil texture

🔴 terms of the energy balance: ground flux and evaporation

G = Rn-H-LE

=> parameterizations for sensible heat flux H and latent heat flux LE

C3. Organization of physical computations

- ISBA : basic equations

sensible heat flux: following Louis 1979

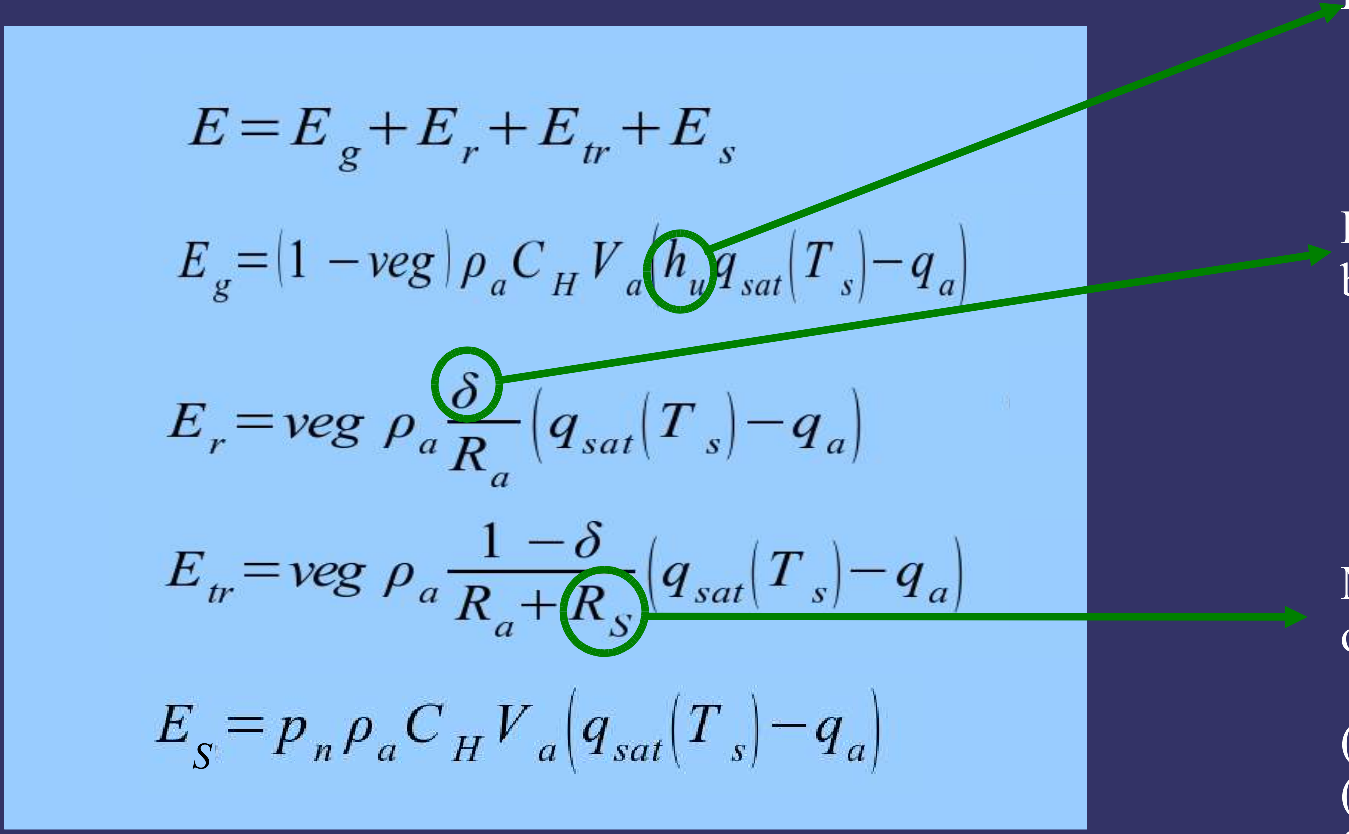
$$H = \rho_a C_p C_H V_a (T_S - T_a)$$

Cp	air specific heat
Ch	turbulent exchange coefficient
Va	wind speed

C3. Organization of physical computations

- ► ISBA : basic equations

latent heat flux:



$$E = E_g + E_r + E_{tr} + E_s$$

$$E_g = (1 - veg)\,\rho_a C_H V_a \left(h_u q_{sat}(T_s) - q_a \right)$$

$$E_r = veg\ \rho_a \frac{\delta}{R_a} \left(q_{sat}(T_s) - q_a \right)$$

$$E_{tr} = veg\ \rho_a \frac{1 - \delta}{R_a + R_S} \left(q_{sat}(T_s) - q_a \right)$$

$$E_S = p_n \rho_a C_H V_a \left(q_{sat}(T_s) - q_a \right)$$

Relative humidity on surface

Fraction of foliage covered by intercepted water

Minimum stomatal resistance of vegetation:

(i) Jarvis formulation (1976)
(ii) Isba-A-gs: Rs depends on CO_2 concentration and of the capability of plants to assimilate it

C3. Organization of physical computations

- ISBA : basic equations

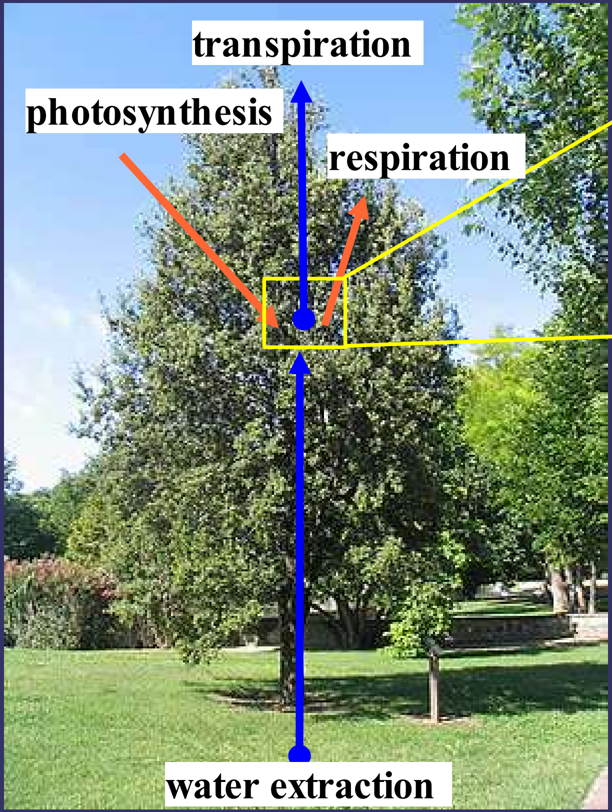
A-gs approach: *the role of stomatal control*

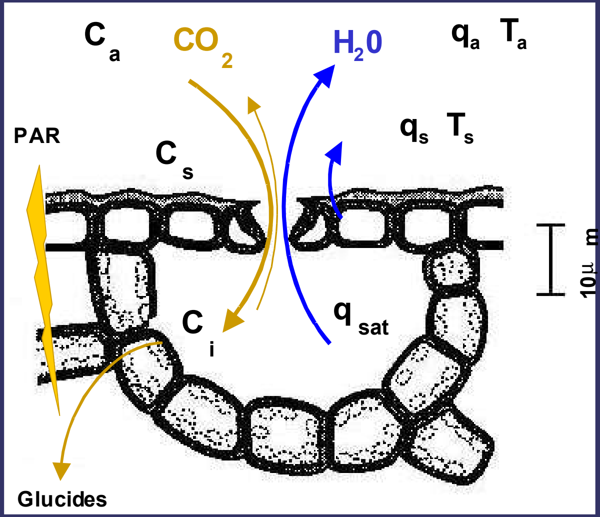
The stomatal aperture controls the ratio:

Photosynthesis/Transpiration

according to the environment conditions

Light, temperature, air humidity
soil moisture, atmospheric [CO$_2$]

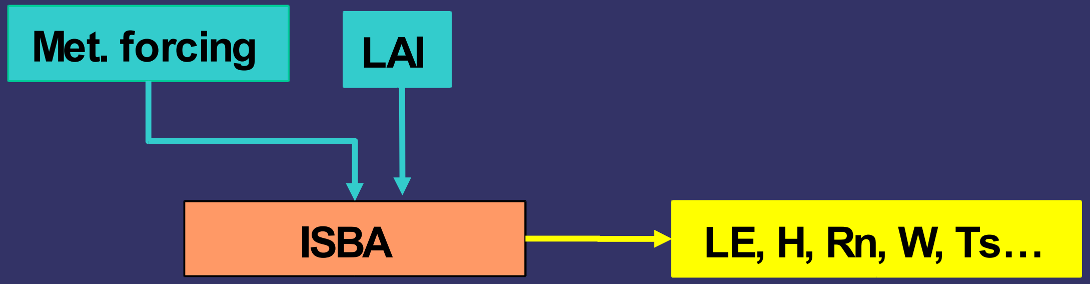




C3. Organization of physical computations

▶ ISBA : basic equations

A-gs approach:

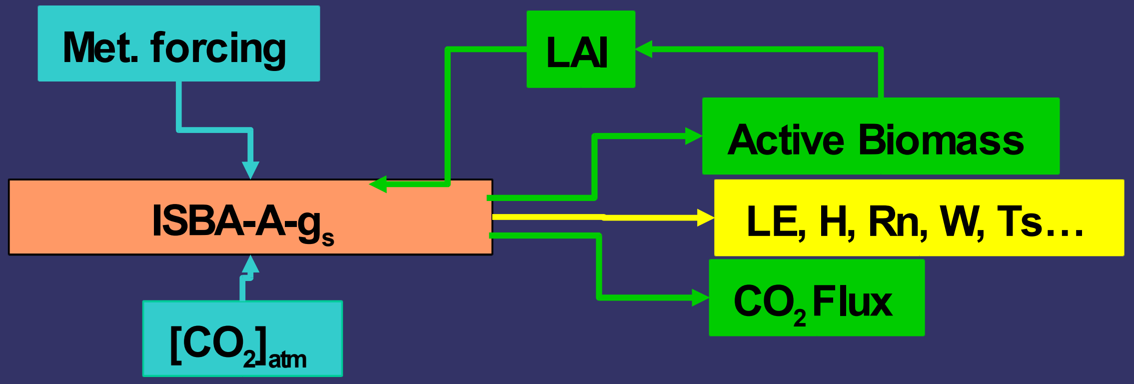


Met. forcing

LAI

ISBA

LE, H, Rn, W, Ts…



Met. forcing

LAI

Active Biomass

ISBA-A-g_s

LE, H, Rn, W, Ts…

$[CO_2]_{atm}$

CO_2 Flux

♦ The active biomass is a reservoir fed by the net CO_2 uptake by leaves
(ie A_n = photosynthesis – leaf respiration)

♦ LAI is computed by the model

C3. Organization of physical computations

► ISBA : basic equations

snow: 3 schemes available in SURFEX

- Douville 95: 1 layer
  albedo, density and swe

- Boone and Etchevers 2000: 3 layers
  albedo, density and heat flux at the interface soil-snow

- Bogatchev and Bazile 2005: 1 layer
  albedo and swe

C3. Organization of physical computations

► ISBA Explicit Snow

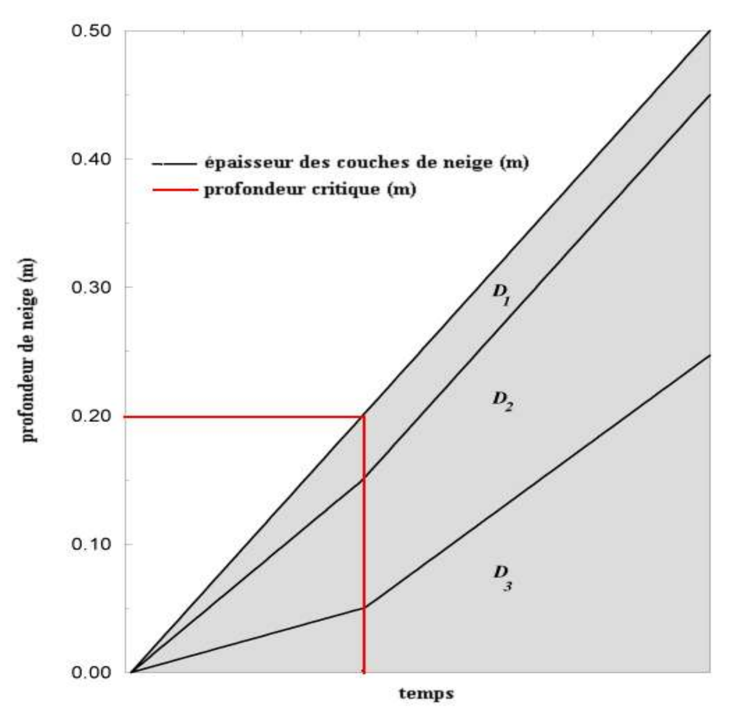
Prognostic variables:

thickness of each snow layer (D)
snow density
snowpack heat content (Hs)

Diagnostic variables:

snow water equivalent
snowpack liquid water (Wl)
snow layer temperature (T)

$$\frac{\partial W_n}{\partial t} = P_n + p_n P_l - E_n - E_{melting}$$



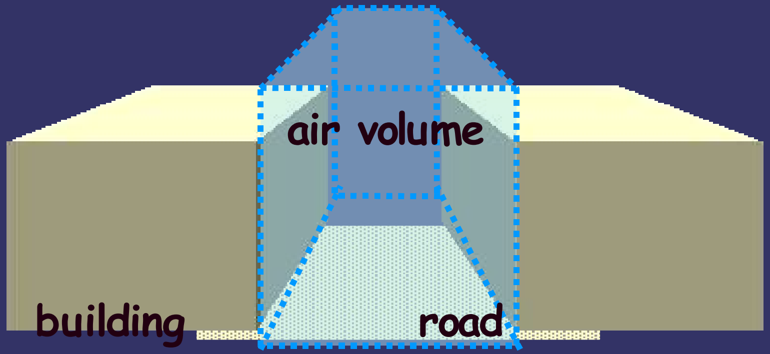
$$D_s = P_n \frac{\Delta t}{\rho_{new}}$$
$$D_{s1} = a_1 D_s + b_1$$
$$D_{s2} = a_2 D_s + b_2$$

Ds is recomputed when snow cover is modified (fresh snowfall, compaction or melting)

C3. Organization of physical computations

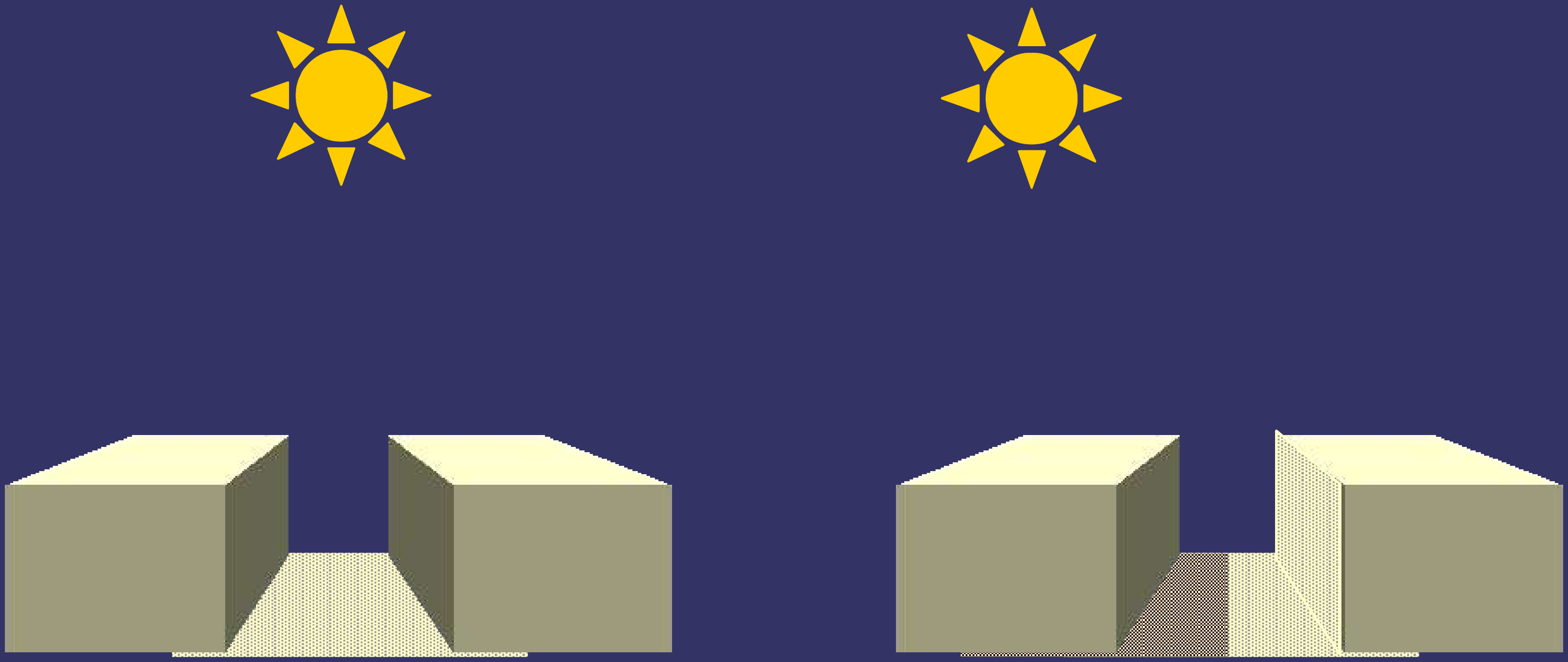
- ► TEB : Town Energy Balance

Urban Canyon concept:



C3. Organization of physical computations

- ► TEB : Town Energy Balance
  - ♦ Radiative perturbations
    - shading effect on walls and roads

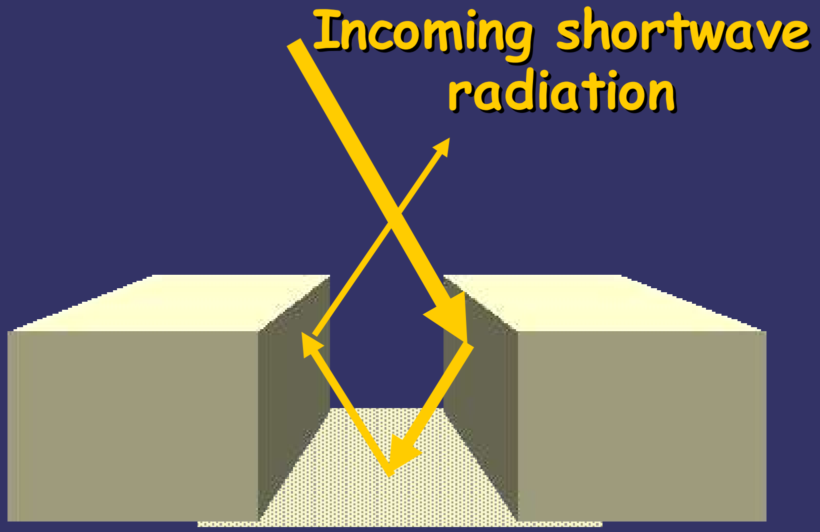


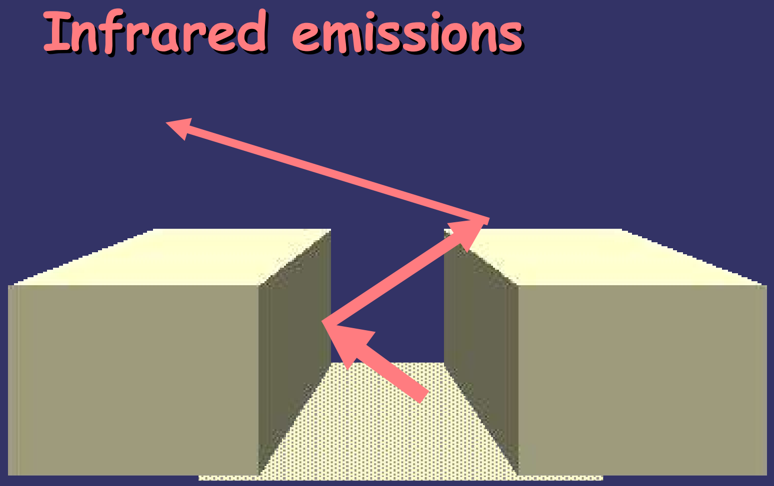
C3. Organization of physical computations

► TEB : Town Energy Balance

♦ Radiative perturbations:

- shading effect on walls and roads
- radiative trapping inside the canyon





C3. Organization of physical computations

► TEB : Town Energy Balance

♦ Radiative perturbations

♦ Thermal perturbations

- specific properties of materials
- lot of available surface

⟶ **Strong heat storage**

C3. Organization of physical computations

► TEB : Town Energy Balance

♦ Radiative perturbations

♦ Thermal perturbations

♦ Anthopogenic emissions

- metabolism
- road traffic
- heating and cooling domestic systems
- industrial areas

C3. Organization of physical computations

► TEB : Town Energy Balance

- ♦ Radiative perturbations
- ♦ Thermal perturbations
- ♦ Anthopogenic emissions
- ♦ Hydrological perturbations
  - sewer network
  - waterproof surfaces

⟶ **Strong runoff and weak evaporation**

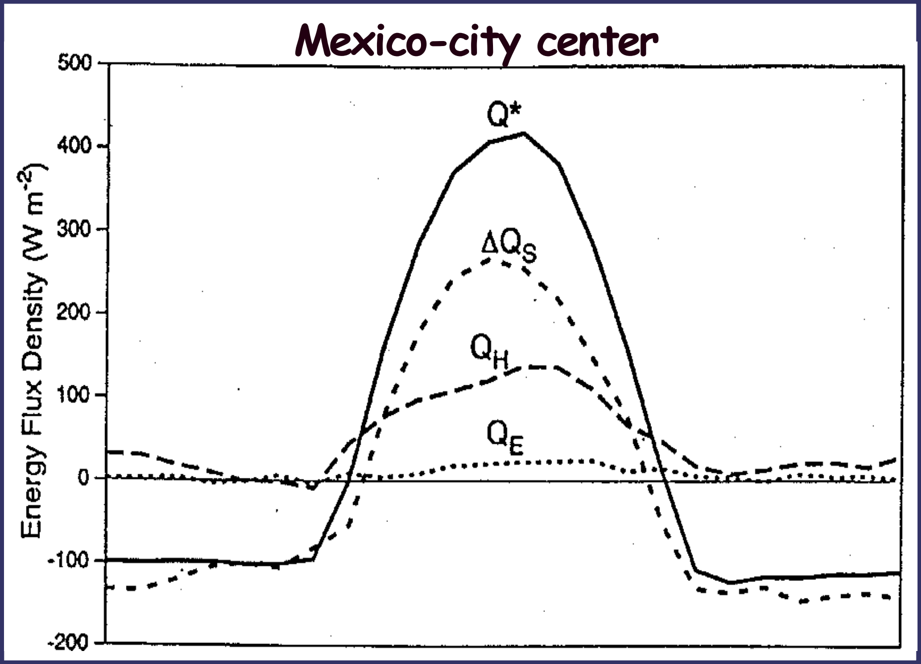
C3. Organization of physical computations

- ► TEB : Town Energy Balance

Urban canopy energy balance:

$$Q^* + Q_F = Q_H + Q_E + \Delta Q_S + \Delta Q_A$$

Q^* : net radiation
Q_F : anthropogenic flux
Q_H : sensible heat flux
Q_E : latent heat flux
ΔQ_S : heat storage flux
ΔQ_A : heat advection net flux



Oke et al., 1999

C3. Organization of physical computations

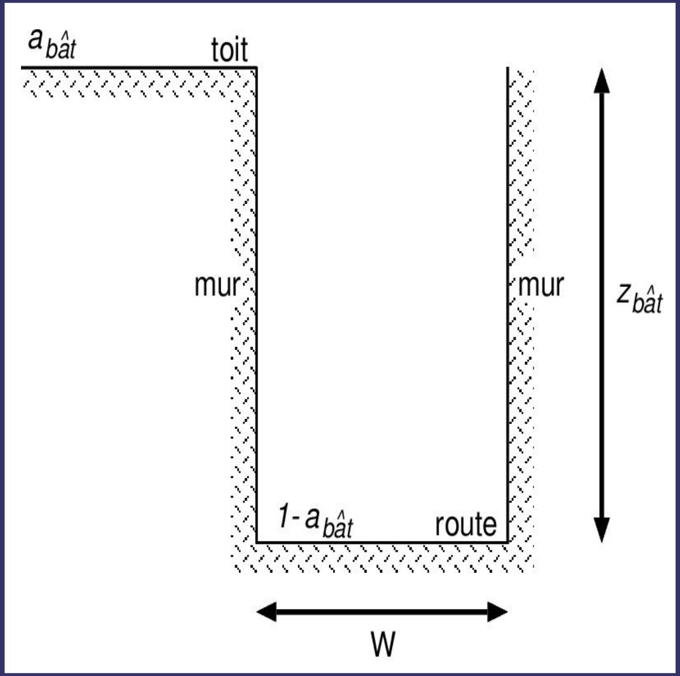
► TEB : Town Energy Balance

✓ Urban canopy model : Parameterization of the exchanges of water and energy between canopy and the atmosphere

✓ Exclusive treatment of built surfaces

✓ Idealized geometry :
Computations are made on a mean urban canyon representative of all roads of the area of interest.

✓ Use of 3 elementary surfaces :
1 roof, 2 identical walls and 1 road

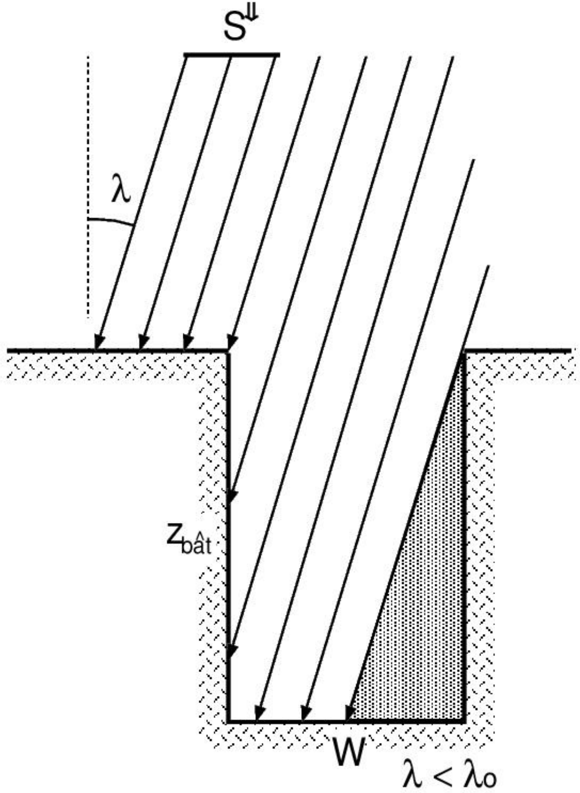


C3. Organization of physical computations

► TEB : Town Energy Balance

1. Computation of the energy budget of each surface:

   - incoming shortwave and longwave radiation
   - fraction of absorbed radiation



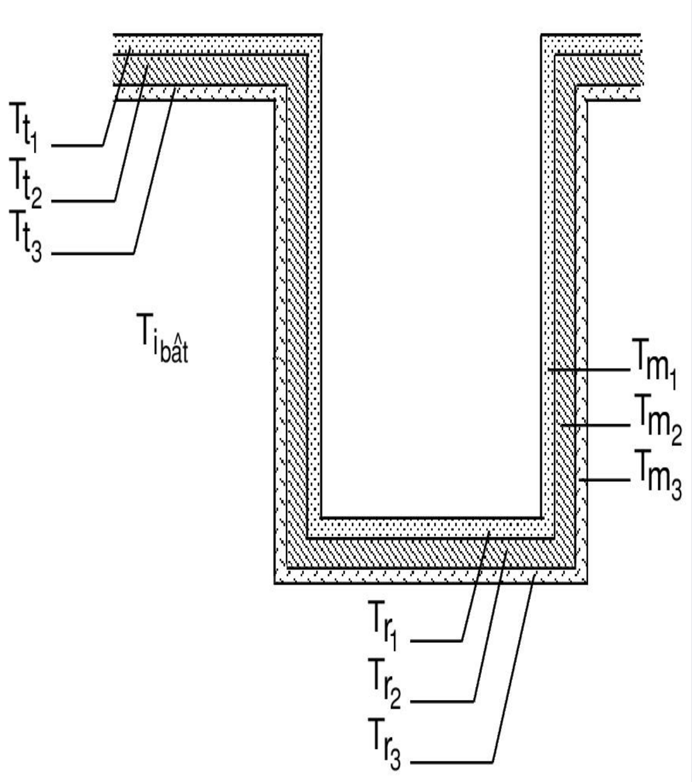
C3. Organization of physical computations

► TEB : Town Energy Balance

1. Computation of the energy budget of each surface:

   - incoming shortwave and longwave radiation
   - fraction of absorbed radiation

2. Computation of the surface temperatures as well as the temperatures of each material layer



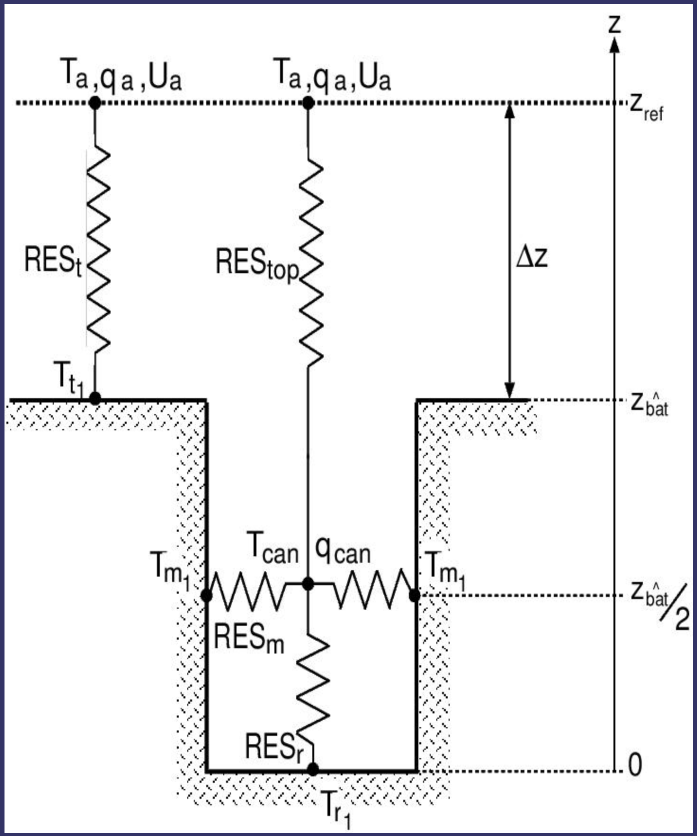
C3. Organization of physical computations

► TEB : Town Energy Balance

1. Computation of the energy budget of each surface:
   - incoming shortwave and longwave radiation
   - fraction of absorbed radiation

2. Computation of the surface temperatures as well as the temperatures of each material layer

3. Computation for each surface of the exchanges of energy with an aerodynamical resistance network



C3. Organization of physical computations

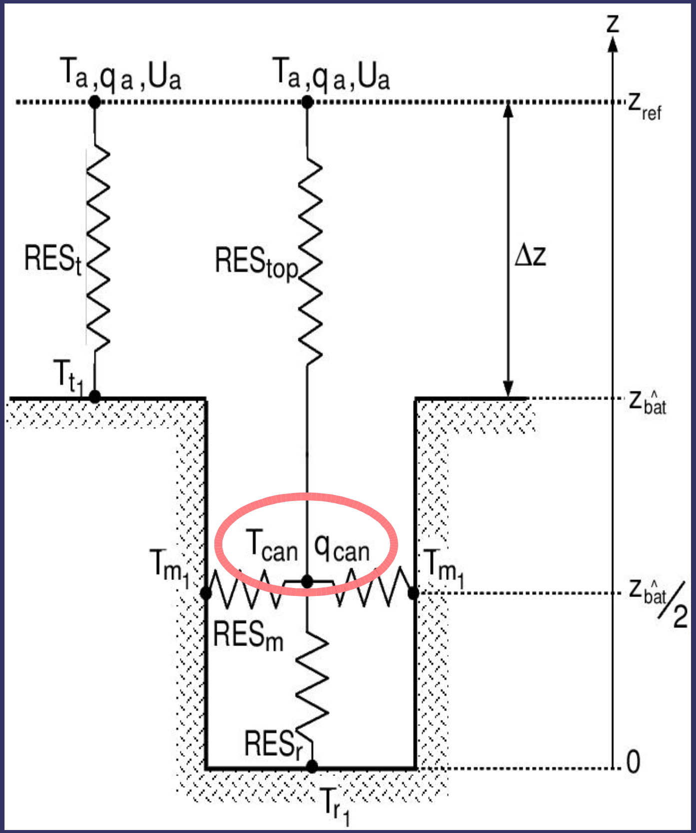
► TEB : Town Energy Balance

1. Computation of the energy budget of each surface:
   - incoming shortwave and longwave radiation
   - fraction of absorbed radiation

2. Computation of the surface temperatures as well as the temperatures of each material layer

3. Computation for each surface of the exchanges of energy with an aerodynamical resistance network

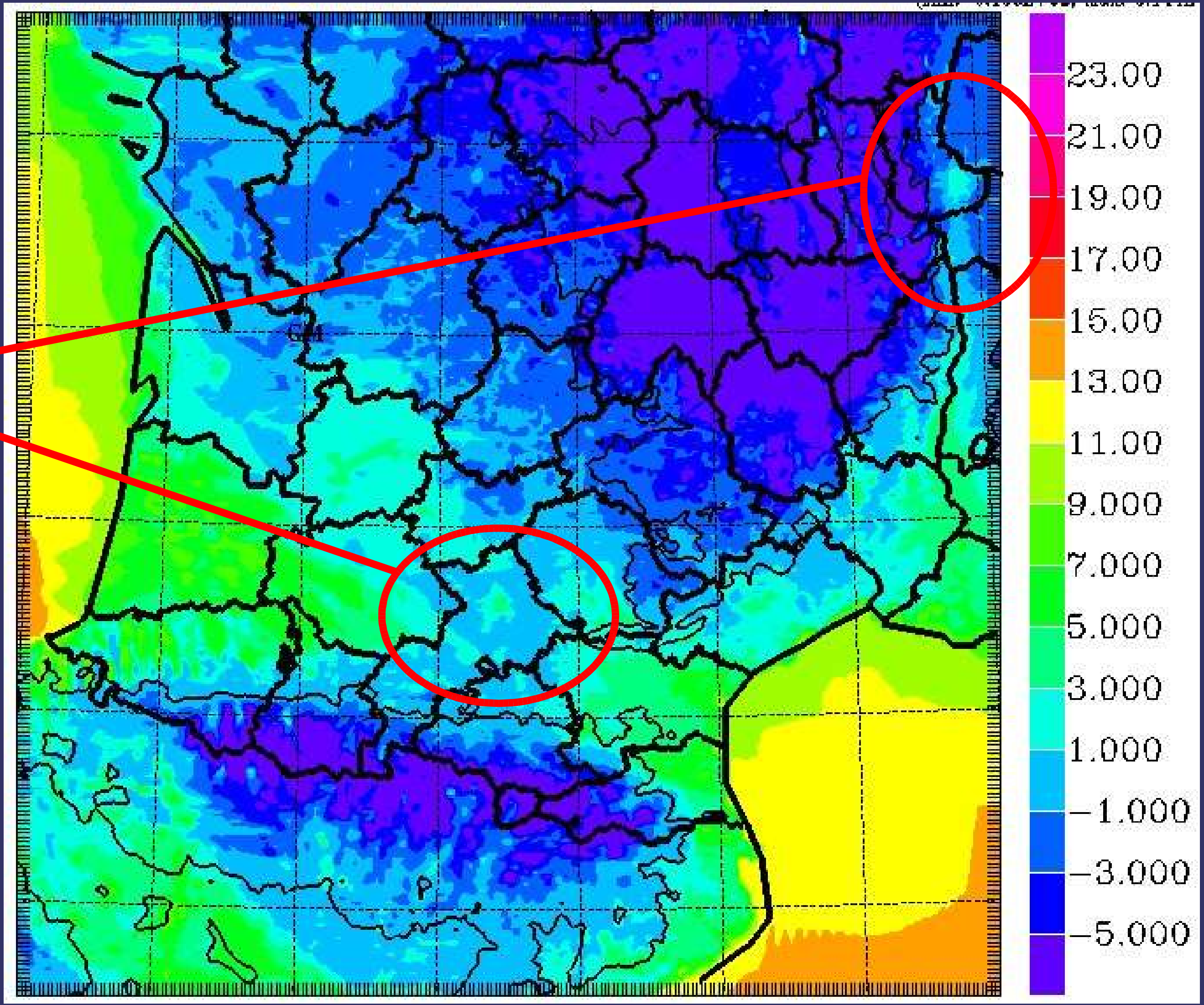
4. Computation of air temperature and humidity inside the canyon



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

C3. Organization of physical computations

- SEA - LAKE :

  no specific model yet

  surface temperature is prescribed

  use of Charnock formulation to compute Z_0 over sea:

  $Z_0 = 0.015 (u^*)^2 / G$ in order to compute turbulent exchange coefficients and then fluxes

Part II. The implementation in Arome and Aladin

D. Coupling with an atmospheric model

E. Technical aspects

D1. Introduction to coupling

- ► Both explicit and implicit coupling are possible within SURFEX
  - ♦ explicit coupling implies that the old atmospheric conditions are used to compute the new surface variables:
    the asumption is that the variation of the atmospheric forcing during time step is small

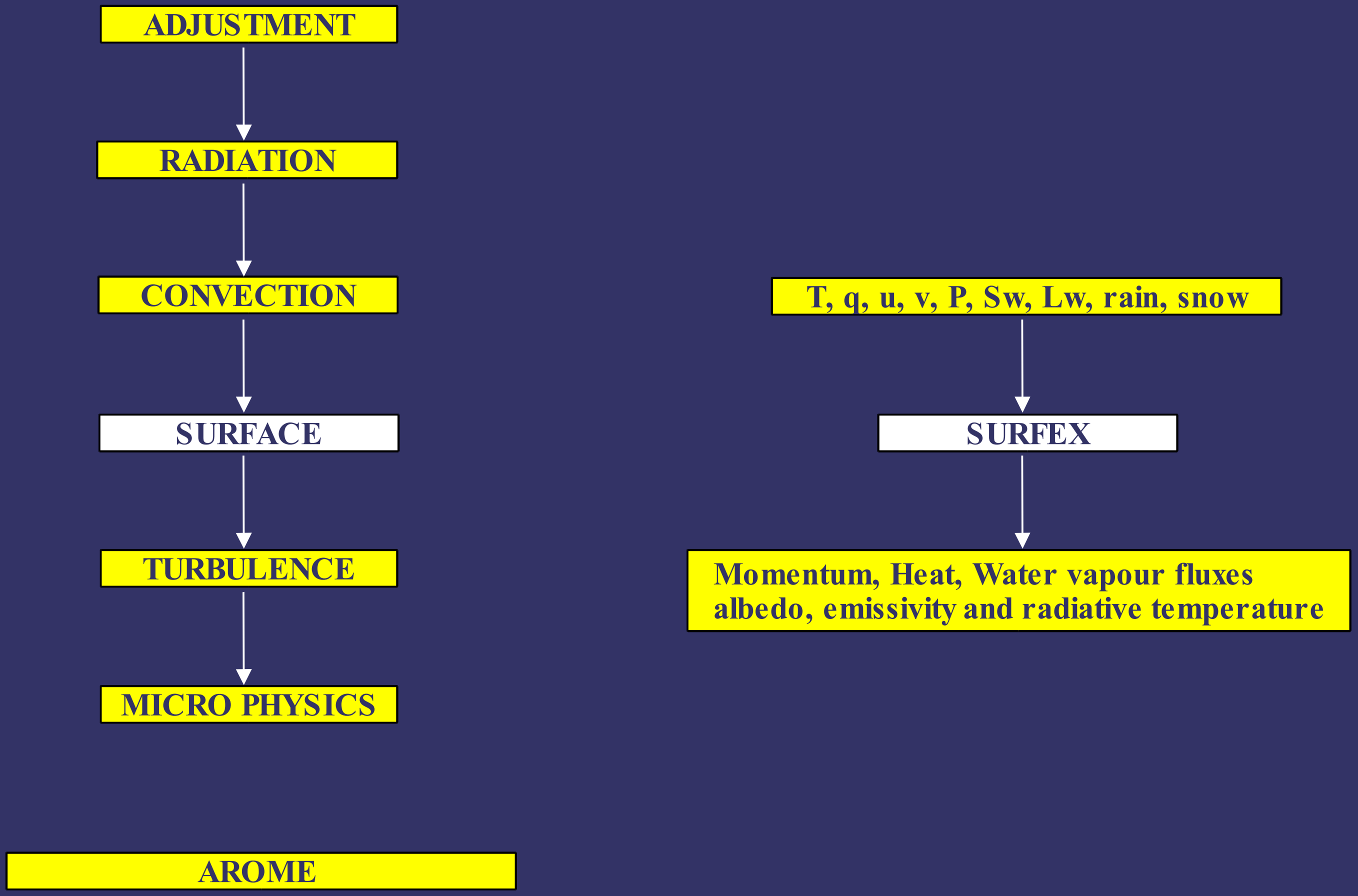
    => well adapted to short time step
  - ♦ implicit coupling implies that new atmospheric conditions are used to compute the new surface variables:

    => longer time-steps
    => more stable scheme

- ► SURFEX follows the set of equations proposed by Best et al. (2004)

D2. Explicit coupling

- Time step loop: surface called before turbulence



ADJUSTMENT

RADIATION

CONVECTION

SURFACE

TURBULENCE

MICRO PHYSICS

AROME

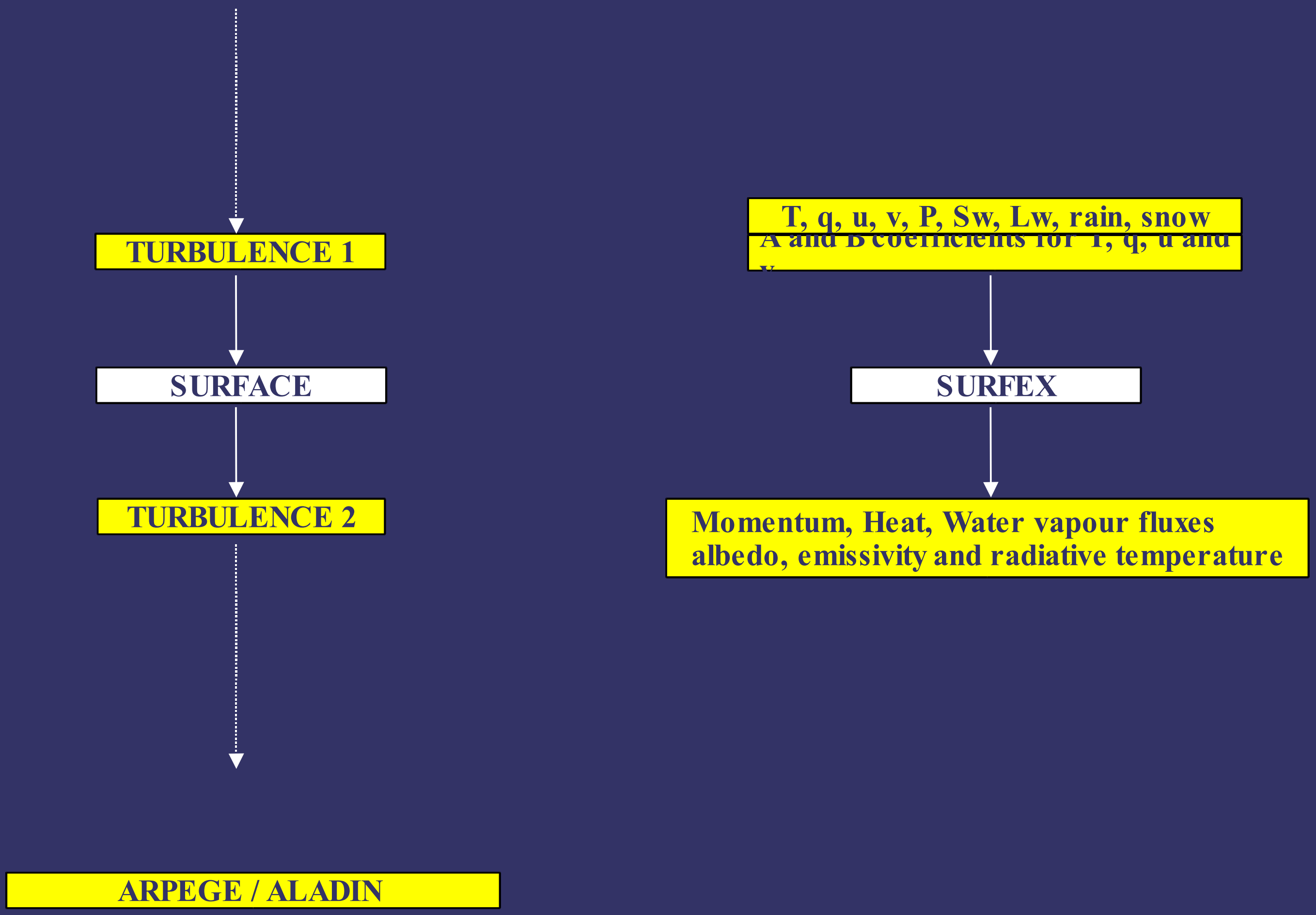
T, q, u, v, P, Sw, Lw, rain, snow

SURFEX

Momentum, Heat, Water vapour fluxes
albedo, emissivity and radiative temperature

D3. Implicit coupling

- ► Time step loop: surface is called in the middle of the vertical diffusion



TURBULENCE 1

SURFACE

TURBULENCE 2

ARPEGE / ALADIN

T, q, u, v, P, Sw, Lw, rain, snow

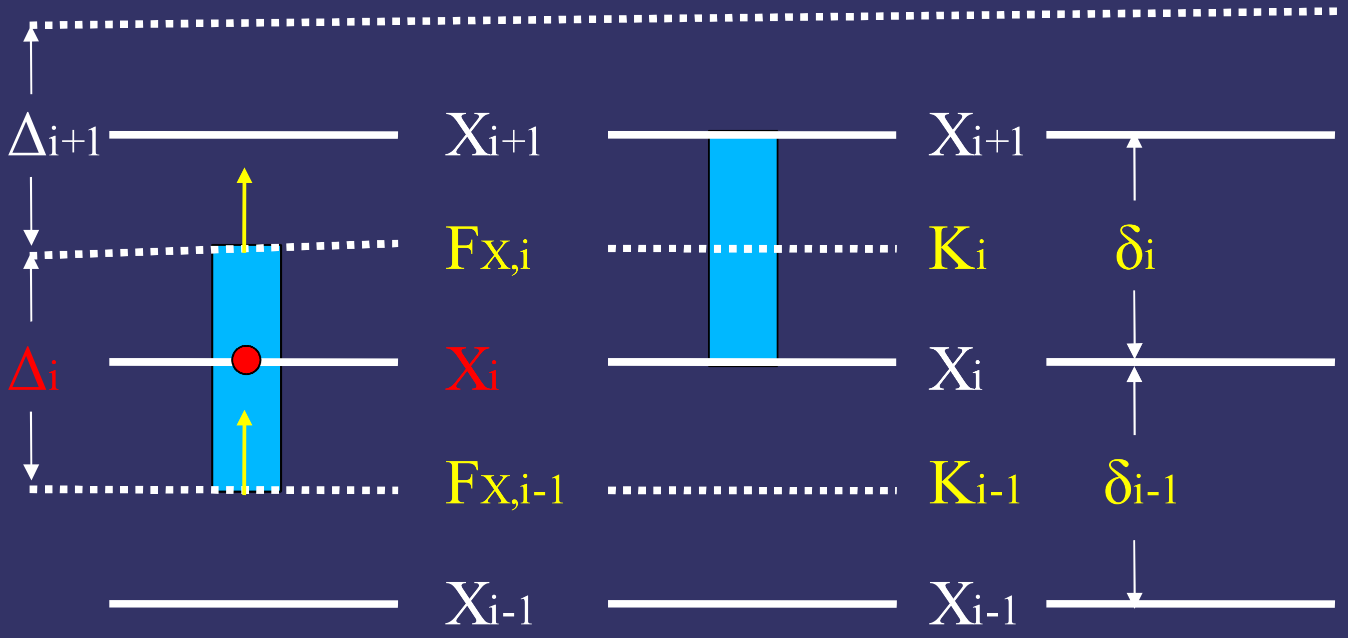
A and B coefficients for T, q, u and v

SURFEX

Momentum, Heat, Water vapour fluxes
albedo, emissivity and radiative temperature

D3. Implicit coupling

- ► The surface variable (u, v, θ, q) evolution is done during resolution of atmospheric vertical diffusion.



$$\frac{X_i^+ - X_i^-}{\Delta t} = \frac{F_{X,i}^+ - F_{X,i-1}^+}{\Delta_i}$$

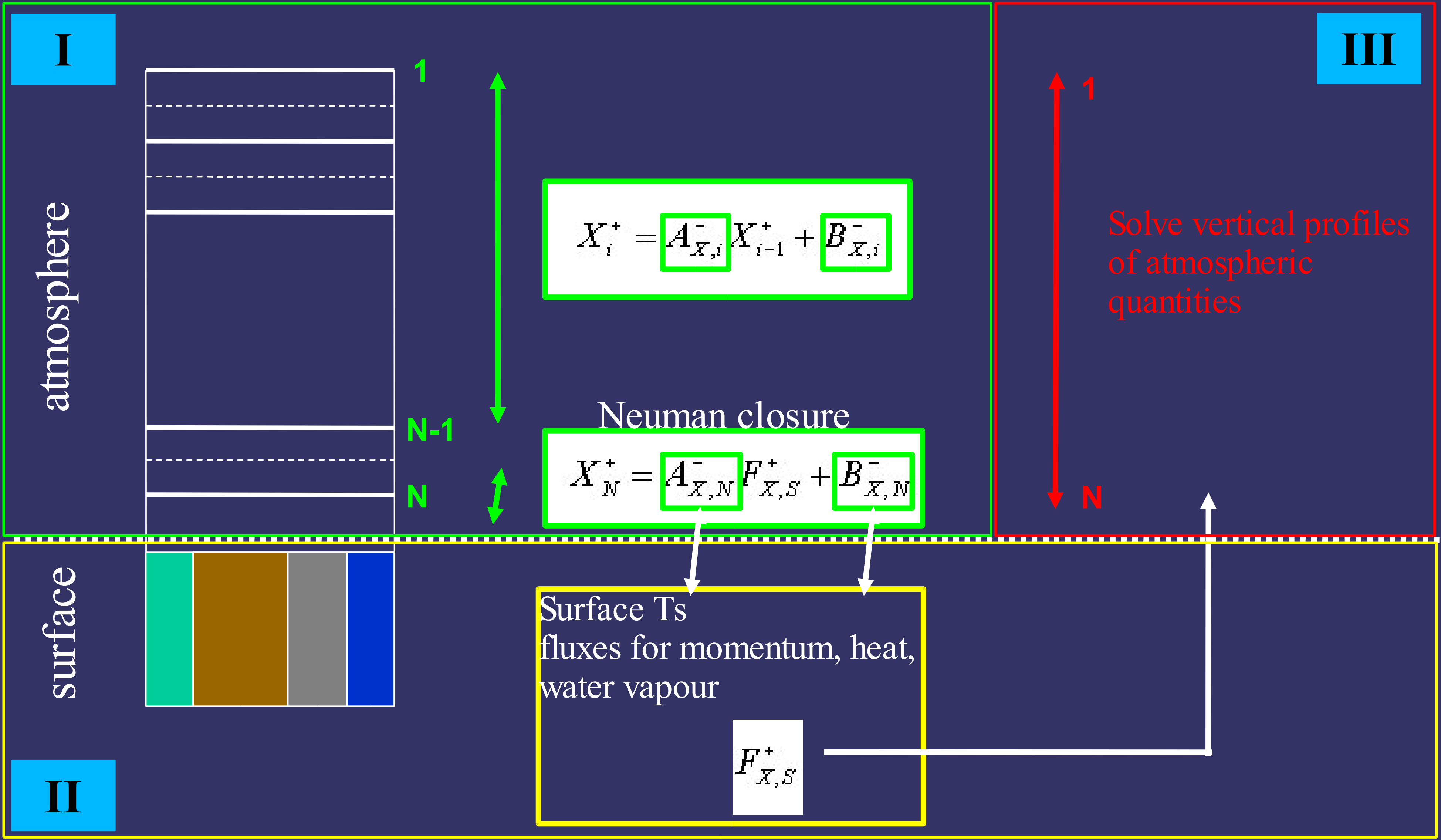
$$F_{X,i} = \frac{k_i}{\delta_i}\left(X_{i+1} - X_i\right)$$

=>

$$X_i^+ = A_{X,i}^- X_{i-1}^+ + B_{X,i}^-$$

D3. Implicit coupling

- ► Vertical diffusion and Neuman closure



$$X_i^+ = \boxed{A_{X,i}^-} X_{i-1}^+ + \boxed{B_{X,i}^-}$$

Neuman closure

$$X_N^+ = \boxed{A_{X,N}^-} F_{X,S}^+ + \boxed{B_{X,N}^-}$$

Surface Ts
fluxes for momentum, heat, water vapour

$$F_{X,S}^+$$

Solve vertical profiles of atmospheric quantities

D4. Type of coupling and model

In case of explicit coupling: AROME, MESONH or OFF-LINE

$A_\theta = A_w = A_q = 0$

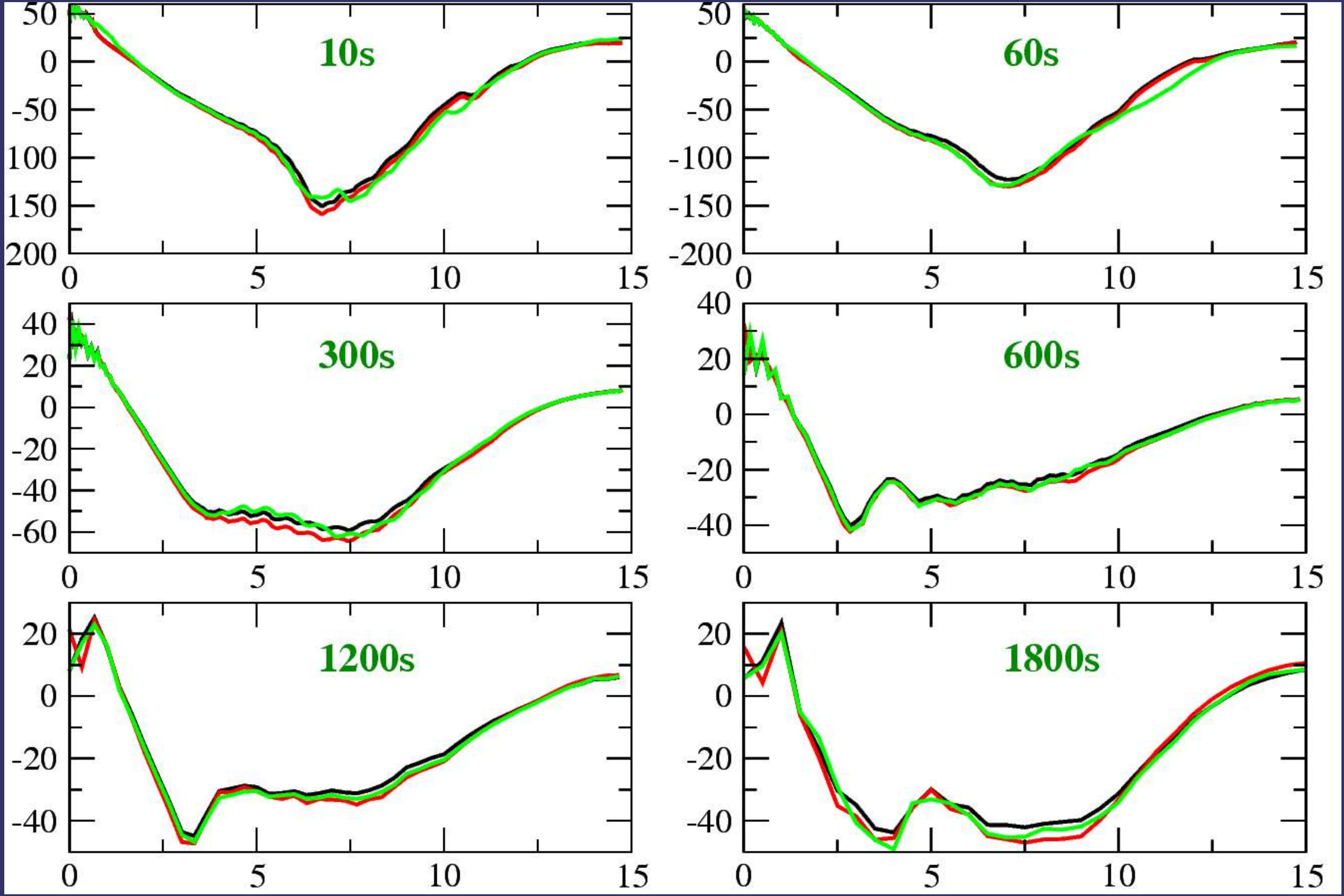
$B_\theta = \theta_A$
$B_q = q_A$
$B_{w^2} = (u_A^2 + v_A^2)$

In case of implicit coupling: ARPEGE / ALADIN or OFF-LINE

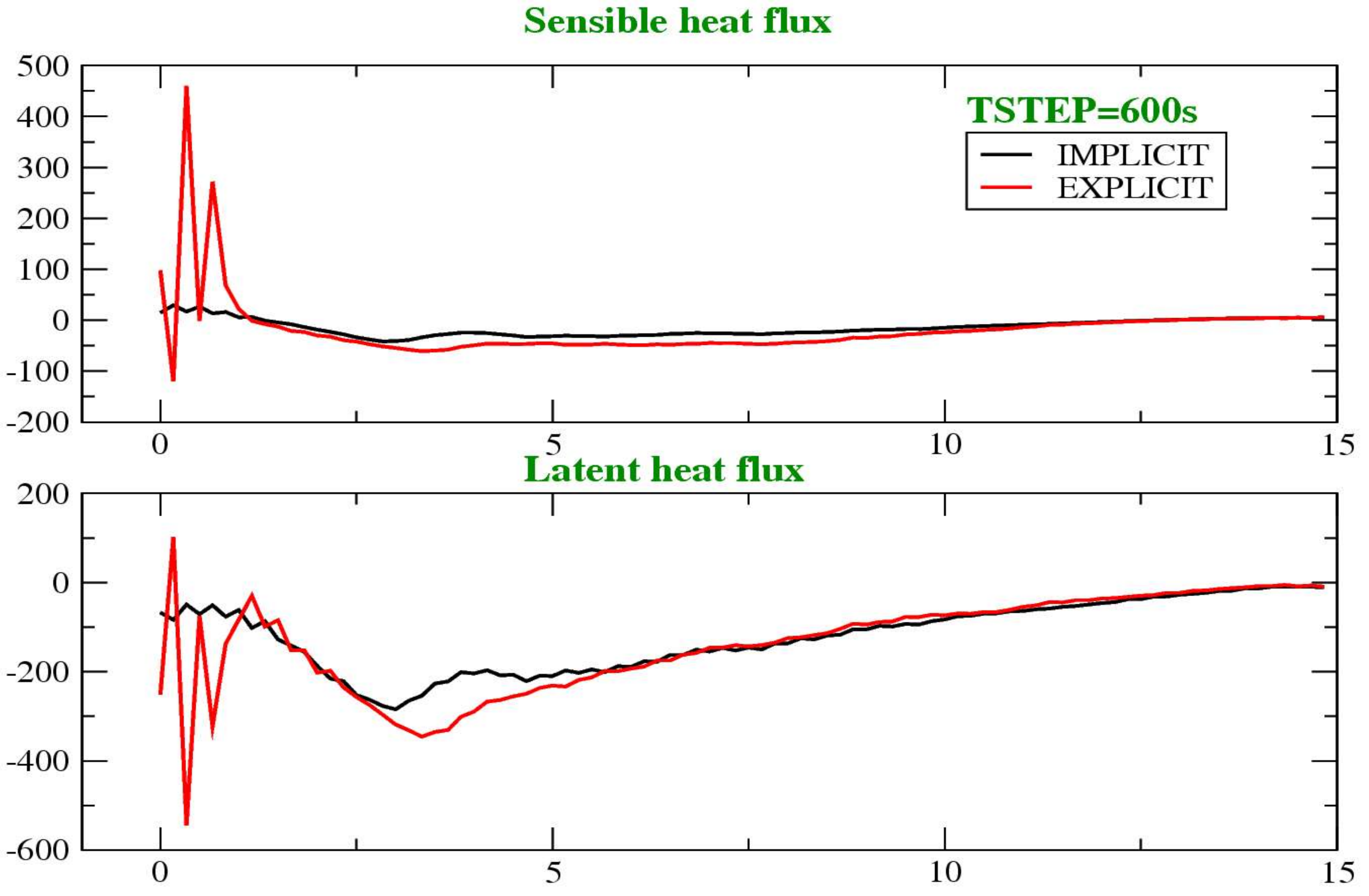
$A_{X,N}$ is a function of $A_{X,N-1}$ and the atmospheric diffusion coefficients between levels N-1 and N
$B_{X,N}$ is a function of the atmospheric diffusion coefficients between levels N-1 and N and also of X_{N-1}

D5. Example of implicit coupling

Eurocs case using 1D Arpege model



D5. Example of implicit coupling



with TSTEP > 600s, the explicit mode is unstable for this case.

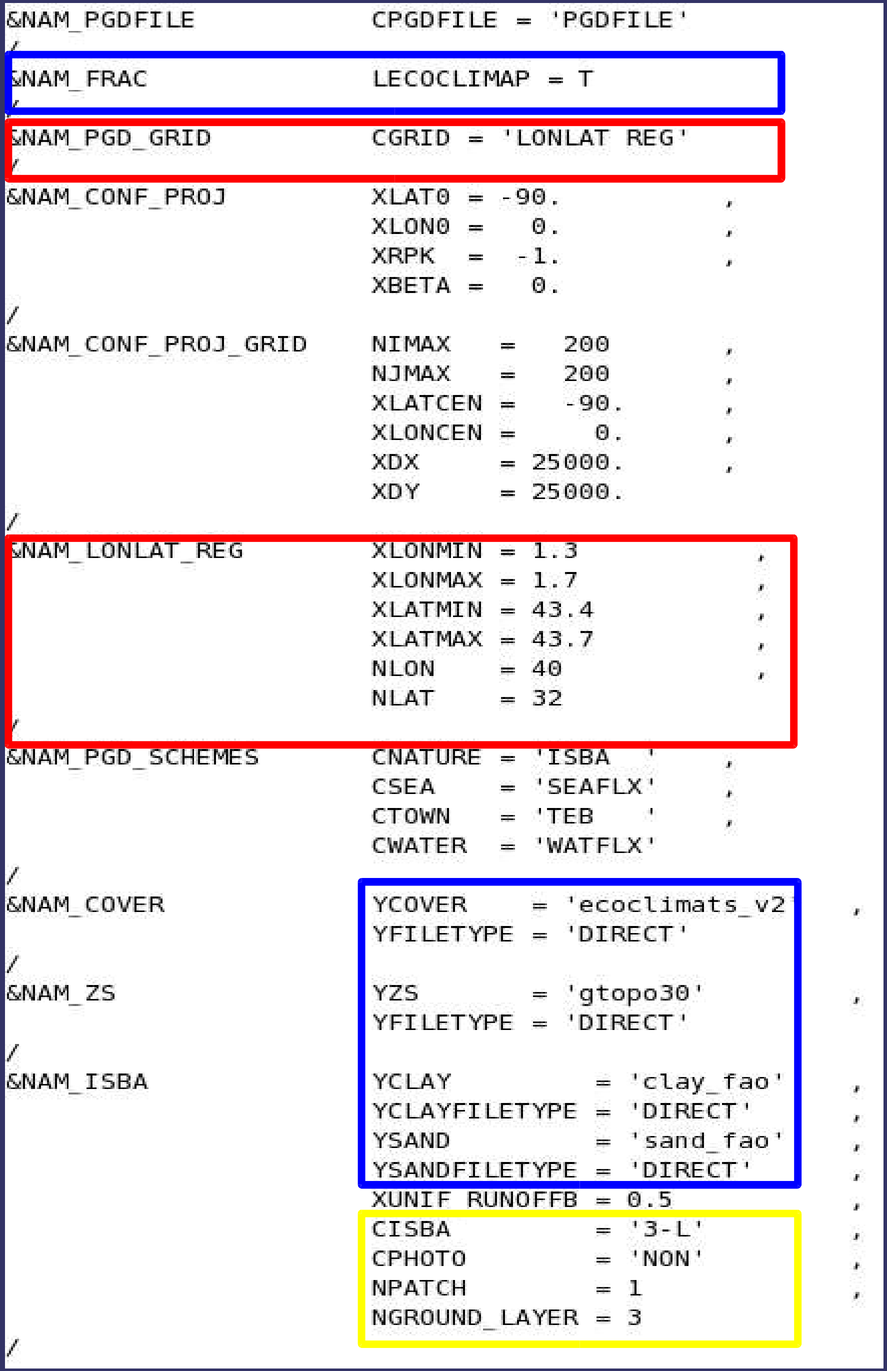
Part II. The implementation in Arome and Aladin

D. Coupling with an atmospheric model

E. Technical aspects

E1. Main namelist options

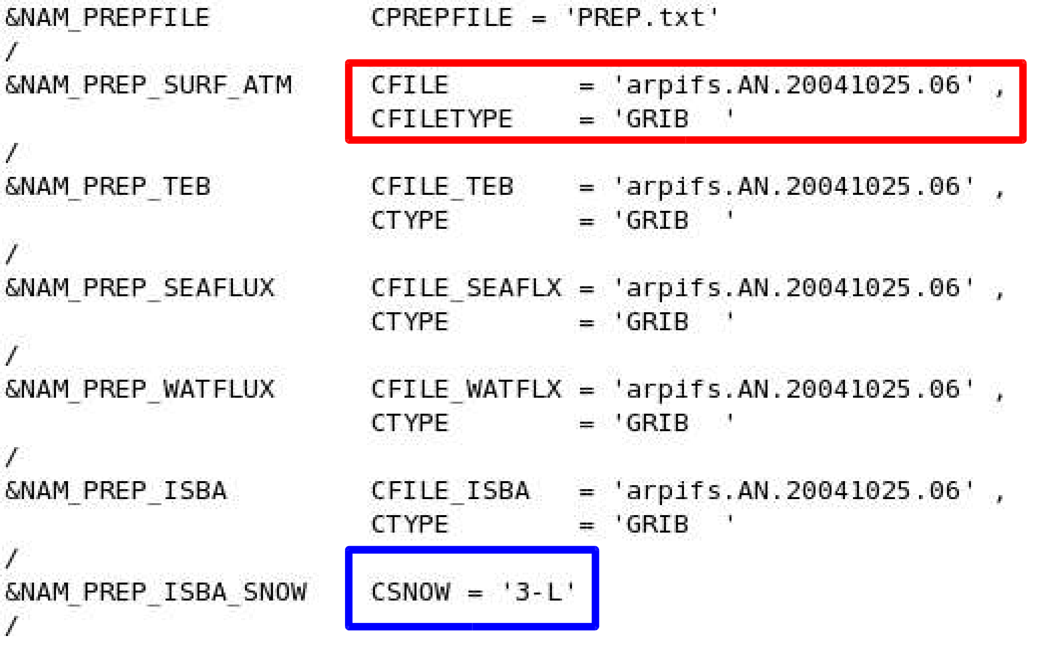
- ► PGD



```
&NAM_PGDFILE           CPGDFILE = 'PGDFILE'
/
&NAM_FRAC              LECOCLIMAP = T
/
&NAM_PGD_GRID          CGRID = 'LONLAT REG'
/
&NAM_CONF_PROJ         XLAT0 = -90.          ,
                       XLON0 =   0.          ,
                       XRPK  =  -1.          ,
                       XBETA =   0.
/
&NAM_CONF_PROJ_GRID    NIMAX   =   200       ,
                       NJMAX   =   200       ,
                       XLATCEN =   -90.      ,
                       XLONCEN =     0.      ,
                       XDX     = 25000.      ,
                       XDY     = 25000.
/
&NAM_LONLAT_REG        XLONMIN = 1.3           ,
                       XLONMAX = 1.7           ,
                       XLATMIN = 43.4          ,
                       XLATMAX = 43.7          ,
                       NLON    = 40            ,
                       NLAT    = 32
/
&NAM_PGD_SCHEMES       CNATURE = 'ISBA  '    ,
                       CSEA    = 'SEAFLX'    ,
                       CTOWN   = 'TEB   '    ,
                       CWATER  = 'WATFLX'
/
&NAM_COVER             YCOVER    = 'ecoclimats_v2'   ,
                       YFILETYPE = 'DIRECT'
/
&NAM_ZS                YZS       = 'gtopo30'         ,
                       YFILETYPE = 'DIRECT'
/
&NAM_ISBA              YCLAY         = 'clay_fao'    ,
                       YCLAYFILETYPE = 'DIRECT'      ,
                       YSAND         = 'sand_fao'    ,
                       YSANDFILETYPE = 'DIRECT'      ,
                       XUNIF RUNOFFB = 0.5           ,
                       CISBA         = '3-L'         ,
                       CPHOTO        = 'NON'         ,
                       NPATCH        = 1             ,
                       NGROUND_LAYER = 3
/
```

E1. Main namelist options

- ► PREP



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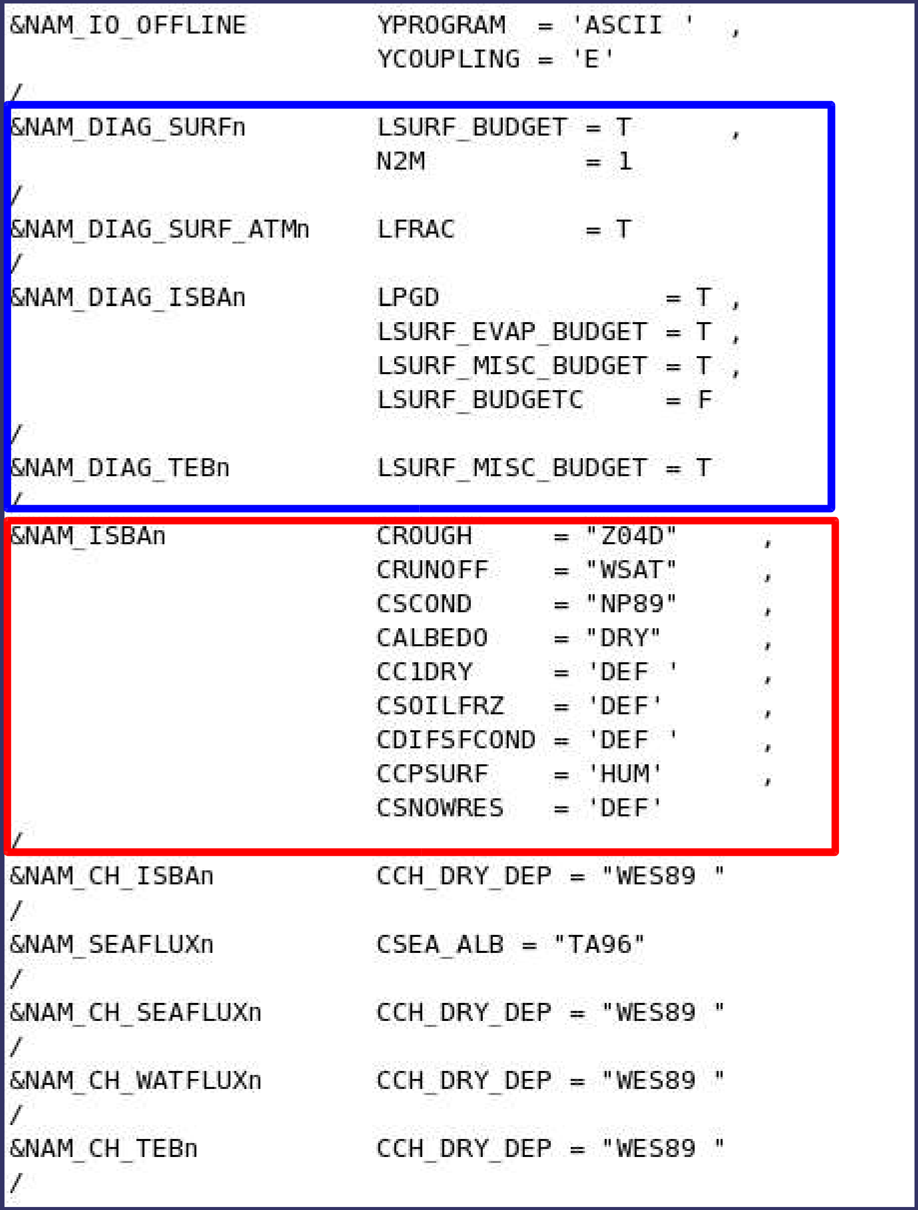
E1. Main namelist options

► OFF-LINE

DIAG

PHYS



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                         LSURF_MISC_BUDGET  = T  ,
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/
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                         CRUNOFF     = "WSAT"      ,
                         CSCOND      = "NP89"      ,
                         CALBEDO     = "DRY"       ,
                         CC1DRY      = 'DEF '      ,
                         CSOILFRZ    = 'DEF'       ,
                         CDIFSFCOND = 'DEF '      ,
                         CCPSURF     = 'HUM'       ,
                         CSNOWRES    = 'DEF'
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/
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/
```

E2. Diagnostics

- SURFEX produces several diagnostics:

  N2M=1 or 2
  temperature, humidity at 2m and wind 10m

  LSURF_BUDGET=T
  net radiation, heat, water vapour and conduction fluxes

  LSURF_EVAP_BUDGET=T
  all ISBA fluxes (evaporation of vegetation, bare ground, sublimation over snow and ice, ...)

  LSURF_MISC_BUDGET=T
  possibility to diagnose specific quantities in ISBA or TEB (roughness length over urban area, halstead coefficient, ...)

E3. Physical options

- ► CROUGH:

  type of orographic roughness length:

  Z01D: orographic roughness length does not depend on wind direction
  Z04D: orographic roughness length depends on wind direction

- ► CRUNOFF:

  type of subgrid runoff:

  WSAT: runoff occurs only when saturation is reached
  DT92 : Dumenil and Todini (1992) subgrid runoff

- ► CSCOND:

  type of thermal conductivity:

  NP89: Noilhan and Planton (1989) formula
  PL98: Peters-Lidar et al. (1998) formula

E3. Physical options (isba only)

► CALBEDO:

type of bare soil albedo:

DRY : dry bare soil albedo
WET : wet bare soil albedo
MEAN: albedo of bare soil half dry, half wet
EVOL : albedo of bare soil evolving with soil moisture

► CC1DRY:

type of C1 formulation for bar soils:

DEF : Giard and Bazile formulation
GB93 : Giordani and Braud (1993) propose a gaussian formulation for C1 force restore coefficient

E3. Physical options (isba only)

- ► CSOILFRZ:

  type of soil freezing physics option:

  DEF : Boone et al. (2000), Giard and Bazile (2000)
  LWT: phase changes as above, but relation between unfrozenwater and temperature is considered

- ► CDIFSFCOND:

  type of mulch effect:

  DEF : no mulch effect
  MLCH: include the insulating effect of litter/mulch on the surface thermal conductivity (decreasing of thermal conductivity)

E3. Physical options (isba only)

- CCPSURF:

  type of specific heat at surface:

  DRY : specific heat does not depend on surface specific humudity surface
  HUM: specific heat depends on surface specific humudity surface

- CSNOWRES:

  type of turbulent exchange over snow:

  DEF: Louis (1979)
  RIL : maximum Richardson number limit for stable conditions