surfex course

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CNRM / GMME

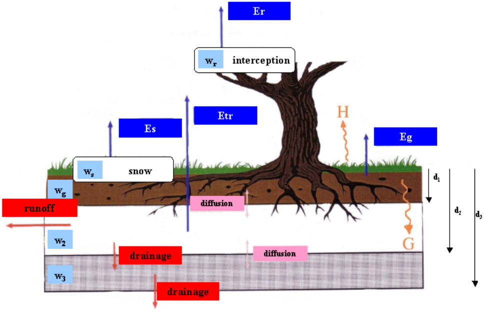
PREP

To initialize prognostic variables of models, namely : ISBA (nature), TEB (town), FLAKE et WATFLX (lakes) ou SEAFLX (sea/ocean)

$$\frac{\partial X}{\partial t} = \cdots \leftarrow \quad X(t=0)$$

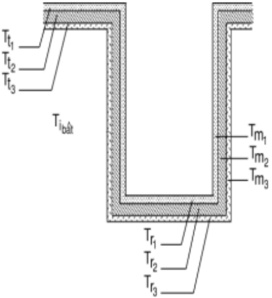
ISBA variables

- vertical profiles of T, w_l et w_i
- interception reservoir water content
- snow water equivalent, albedo, ...



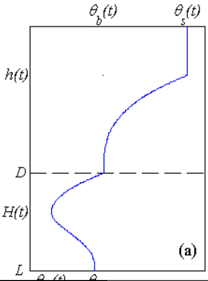
TEB variables

- roof, walls and road temperatures
- roof water content
- road water content



FLAKE variables

- surface temperature
- mixing layer depth
- lake deep temperature
- mean water temperature
- shape of profile



WATFLX/SEAFLX variables

- surface temperature

kept constant during the run

CMO1D variables

- surface temperature
- salinity
- current
- turbulent kinetic energy

initialization

uniform initialization

values at z=0 meters height

initialization from a file

atmospheric or ocean model type :
ECMWF, ARPEGE, ALADIN, Meso-NH, MOCAGE, MERCATOR
lat lon value type :
only for some fields (T and w_l of ISBA)

principle

Isba variables

- reading of atmospheric fields
- projection on a detailed soil grid (20 layers)
- horizontal interpolations on the fine grid
- vertical interpolations on the target grid
- back to model variables

example

To initialize all prognostic variables from an ECMWF grib file, except Isba temperature and humidity profiles from external files :

```
&NAM_PREP_SURF_ATM
CFILE='ecmwf.OD.20050526.18',CFILETYPE='GRIB ' /

&NAM_PREP_TEB
CFILE_TEB ='ecmwf.OD.20050526.18',CTYPE='GRIB ' /

&NAM_PREP_SEAFLUX
CFILE_SEAFLX='ecmwf.OD.20050526.18',CTYPE='GRIB ' /

&NAM_PREP_WATFLUX
CFILE_WATFLX='ecmwf.OD.20050526.18',CTYPE='GRIB ' /

&NAM_PREP_ISBA
CFILE_ISBA ='ecmwf.OD.20050526.18',CTYPE='GRIB ' ,
CFILE_HUG_SURF = 'SWI1_SIM_2005052618_ALL' ,
CFILE_HUG_ROOT = 'SWI2_SIM_2005052618_ALL' ,
CFILE_HUG_DEEP = 'SWI3_SIM_2005052618_ALL' ,
CFILE_TG_SURF = 'TG1_SIM_2005052618_ALL' ,
CFILE_TG_ROOT = 'TG2_SIM_2005052618_ALL' ,
CFILE_TG_DEEP = 'TG3_SIM_2005052618_ALL' ,
CTYPE_HUG = 'ASCLLV', CTYPE_TG = 'ASCLLV' /
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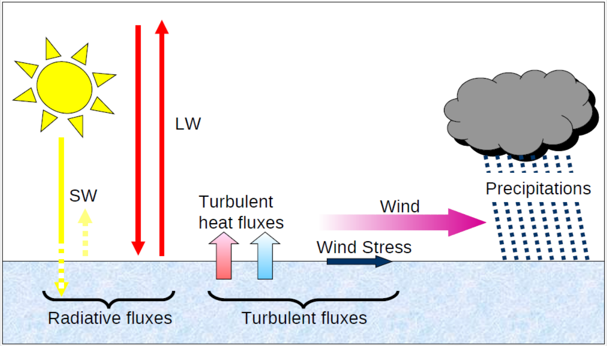
practical exercise

subject available on training course web page

Lakes/Oceans

air-water exchanges



surface fluxes

Bulk method

surface turbulent fluxes are related to gradients of meteorological variables by a set of exchange coefficients that depend on the atmosphere stratification :

$$Q_{mom} = \rho \cdot \overline{w'U'} \qquad Q_{sen} = \rho \cdot C_p \cdot \overline{w'\theta'} \qquad Q_{lat} = \rho \cdot L_v \cdot \overline{w'q'}$$

$$\overline{w'\eta'} = -C_\eta \cdot \Delta U \cdot \Delta \eta$$

the exchanges
surface fluxes
exchange coefficients
1D-Ocean Mixed Layer model
model equations
examples
FLake lake model

surface fluxes

kinematic fluxes

kinematic fluxes can be expressed through the caracteristic scales u_*, θ_* and q_* as follows :

$$\overline{w'U'} = -{u_*}^2 = -C_D \cdot (\Delta U)^2$$

$$\overline{w'\theta'} = -u_* \cdot \theta_* = -C_H \cdot \Delta U \cdot \Delta\theta$$

$$\overline{w'q'} = -u_* \cdot q_* = -C_E \cdot \Delta U \cdot \Delta q$$

exchange coefficients

the goal is equivalent to calculating C_D, C_H and C_E coefficients to know surface fluxes

direct approch

- from atmosphere stability (R_I), one deduces C_D for a given z_0 of 10^{-3}
- then u_* and Q_{mom}
- Charnock approach gives : $z_0 = 0.015 \frac{{u_*}^2}{g}$
- one can then deduce C_H et C_E
- and finally Q_{sen} and Q_{lat} knowing the water surface temperature, maintained constant during the run

exchange coefficients

iterative approch

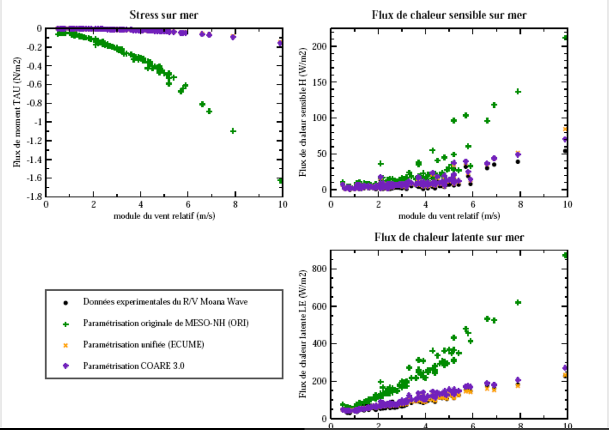
based on the iterative computation of u_*, θ_* and q_*

ECUME on sea/ocean

neutral exchange coefficients are calibrated according to the 10m wind speed measured during field campaigns (Pomme, Equalant, Albatros, ...)

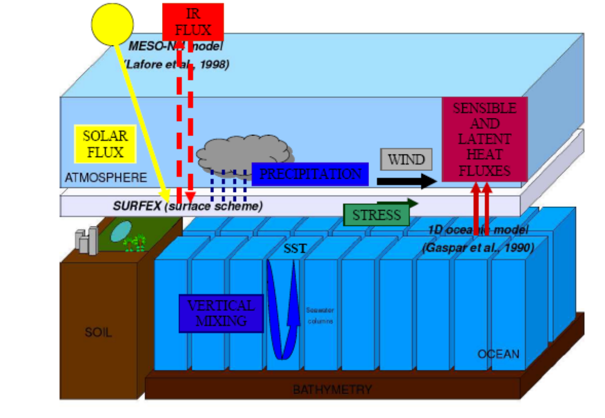
ECUME

impact on fluxes



sea/oceans

1D-Ocean Mixed Layer model



model equations (1)

a variable is decomposed into mean + fluctuation

$$\alpha = \bar{\alpha} + \alpha' \quad ; \quad \textit{temperature } T, \ \textit{salinity } S, \ \textit{currant } \vec{u}, TKE \ e$$

equations

$$\frac{\partial T}{\partial t} = \frac{F_{sol}}{\rho_0 C_p} \frac{\partial I(z)}{\partial z} - \frac{\partial \overline{w' T'}}{\partial z}$$

$$\frac{\partial S}{\partial t} = -\frac{\partial \overline{w' S'}}{\partial z}$$

$$\frac{\partial u}{\partial t} = fv - \frac{\partial \overline{w' u'}}{\partial z}$$

$$\frac{\partial v}{\partial t} = -fu - \frac{\partial \overline{w' v'}}{\partial z}$$

upper boundary condition

$$\overline{w' T'}(0) = -(Q_{sen} + Q_{lat} + F_{IR})/(\rho_0 C_p)$$

$$\overline{w' S'}(0) = (P - Evap)/(\rho_0 C_p)$$

$$\overline{w' u'}(0) = -\tau_u/(\rho_0 C_p)$$

$$\overline{w' v'}(0) = -\tau_v/(\rho_0 C_p)$$

model equations (2)

system closure

$$\overline{w'T'} = -K \cdot \frac{\partial \overline{T}}{\partial z}$$

$$\overline{w'S'} = -K \cdot \frac{\partial \overline{S}}{\partial z}$$

$$\overline{w'u'} = -K \cdot \frac{\partial \overline{u}}{\partial z}$$

$$\overline{w'v'} = -K \cdot \frac{\partial \overline{v}}{\partial z}$$

diffusivity coefficient

$$K = c_k \cdot l_k \cdot \overline{e}^{1/2}$$

turbulent kinetic energy : $e = \frac{1}{2}(u'^2 + v'^2 + w'^2)$

$$\frac{\partial \overline{e}}{\partial t} = -\frac{\partial}{\partial z}\left(\overline{w'e} + \frac{1}{\rho_0}\overline{w'p'}\right) - \left(\overline{w'u'}\frac{\partial \overline{u}}{\partial z} + \overline{w'v'}\frac{\partial \overline{v}}{\partial z}\right) + \overline{b'w'} - \epsilon$$

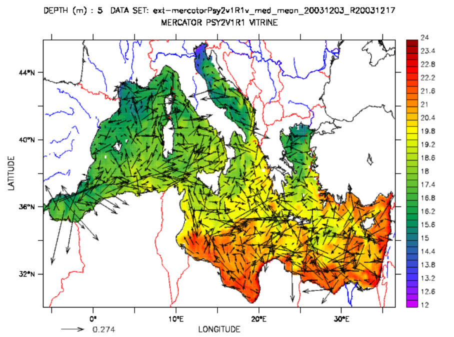
$$-\frac{\partial}{\partial z}\left(\overline{w'e} + \frac{1}{\rho_0}\overline{w'p'}\right) = -K_e \cdot \frac{\partial \overline{e}}{\partial z}$$

$$K_e = c_\epsilon \cdot l_\epsilon \cdot \overline{e}^{1/2}$$

$$b = \frac{g}{\rho_0}(\rho - \rho_0) \qquad \rho = \rho(T, S)$$

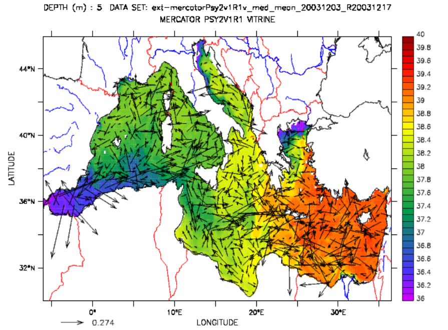
$$\epsilon = c_\epsilon \cdot l_\epsilon \cdot \overline{e}^{3/2}$$

temperature initialization



temperature (degC) and current (m/s)

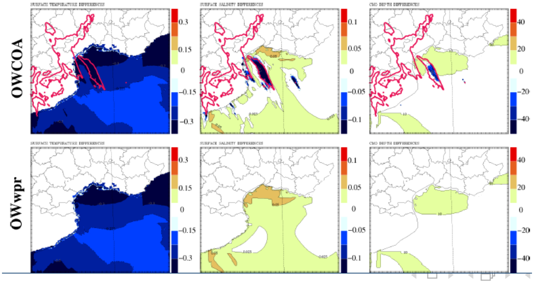
salinity initialization



salinity (degC) and current (m/s)

response to heavy rainfall : Aude November, 12, 1999 at 21TU

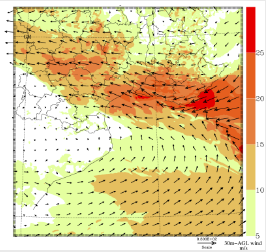
- freshwater supply
- decrease of salinity
- increase of stratification
- lower temperature

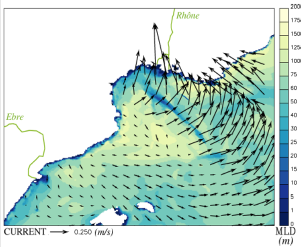


response to a strong jet

Hérault case : Decembre, 4, 2003 at 00TU

- eastern wind (Rhône delta)
- creation of a surface current
- potential perturbation of the river runoff



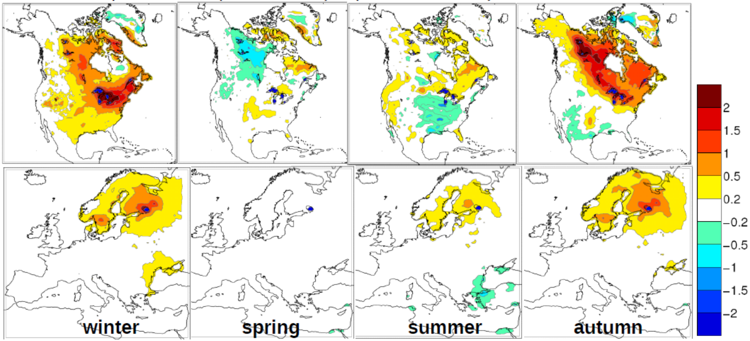


Why focus on lakes ?

- a lake can affect the boundary layer structure and therefore the sensible weather
- it depends on its size, shape and on the meteorological situation
- lake coverage is large in boreal regions or in the american Great lakes region (for example)

impact in a climate model

2m-air-temperature for (lake version) – (no lake version):

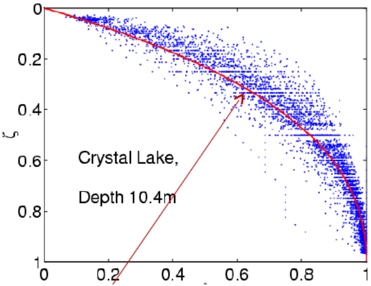


- 3D-models are detailed but too expensive (CPU)
- multi-layer 1D-models : expensive
- one-layer 1D-model : big errors (never stratified)
- FLake : 2-layers 1D-model
  - vertical profile is parameterized
  - low CPU cost
  - realistic physics

"self-similarity" concept

temperature profile in the thermocline can be parameterized by a universal function of the depth (adimentionned), 4th order polynomial

$$\Phi(\zeta) = \frac{\theta_s(t) - \theta(z,t)}{\Delta\theta(t)} \quad ; \quad \zeta = \frac{z - h(t)}{\Delta h(t)}$$

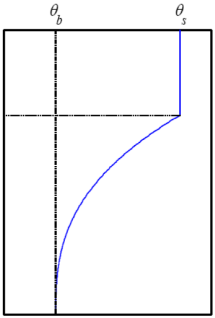


$\theta(z,t) = \theta_s(t)$ *in the mixed layer*

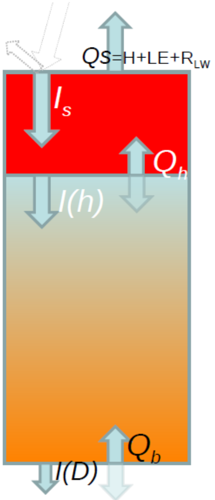
$\theta(z,t) = \theta_s(t) - (\theta_s(t) - \theta_b(t))\Phi(\zeta)$ *in the thermocline*

- temperatures θ_s, θ_b
- thickness of the mixed layer h
- $C_T = \int_0^1 \Phi(\zeta) d\zeta$
- mean temperature $\overline{\theta}$

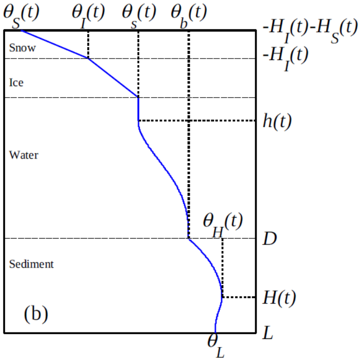
$$\overline{\theta} = \theta_s - C_T(1 - \frac{h}{D})(\theta_s - \theta_b)$$



- conservation of the total energy :
  $\rho_w c_w D \frac{d\bar{\theta}}{dt} = Q_s - Q_b + I_s - I(D)$
- conservation of the mixed layer
  $\rho_w c_w h \frac{d\theta_s}{dt} = Q_s - Q_h + I_s - I(h)$
- h evolution : computed by accounting for convective and stable regimes
- C_T evolution : computed by a relaxation equation with caracteristic time being proportionnal to $(D-h)^2$



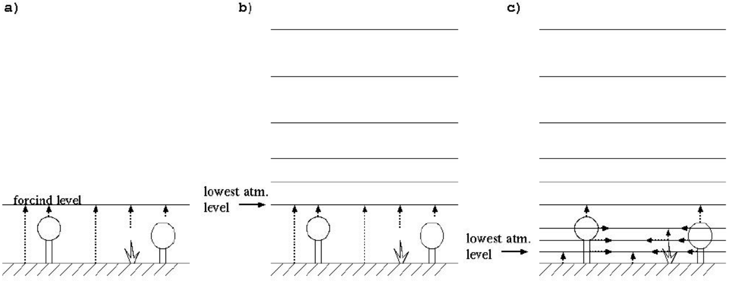
- sediments module
- surface freezing
- snow on ice



SBL : a surface boundary layer model for urban areas

- in atmospheric models, urban schemes are multi-layers or single-layer
- single-layer schemes are generally efficient
- multi-layers schemes better describe the air in the canyon. But their implementation rely very complex.
- SBL scheme is efficient and easy to implement

the different schemes

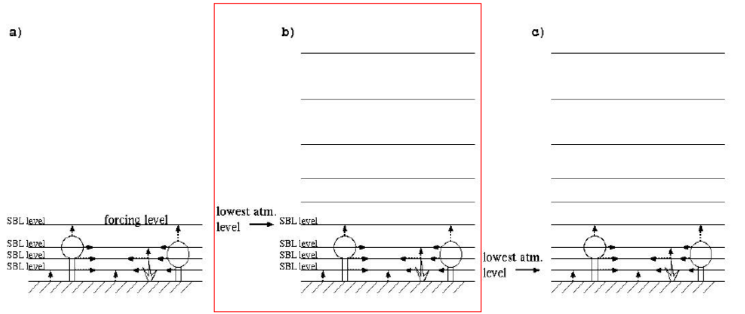


"single-layer" surface scheme forced off-line

"single-layer" surface scheme coupled to an atmospheric model

"multi-layer" surface scheme coupled to an atmospheric model

SBL scheme



"single-layer" surface scheme + Surface Boundary Layer scheme forced offline

"single-layer" surface scheme + Surface Boundary Layer scheme coupled to an atmospheric model

"multi-layer" surface scheme coupled to an atmospheric model

SBL assumptions

That of a classical surface boundary layer :

- mean wind direction does not vary in the surface layer
- turbulent transport and advection of TKE are small as compared as the others terms
- constant flux layer above the canopy
- large scale forcing are uniform with height

principle of SBL

- takes into account the effects of obstacles in the grid cell : large-scale forcing, introduction of a drag force (deceleration of streamflow), heating/cooling, drying/moistening and small-scale TKE production.

$$\frac{\partial U}{\partial t} = \frac{\partial U}{\partial t}(z_a) + Turb(U) + Drag(U)$$

$$\frac{\partial \theta}{\partial t} = \frac{\partial \theta}{\partial t}(z_a) + Turb(\theta) + \frac{\partial \theta}{\partial t}$$

$$\frac{\partial q}{\partial t} = \frac{\partial q}{\partial t}(z_a) + Turb(q) + \frac{\partial q}{\partial t}$$

$$\frac{\partial ECT}{\partial t} = Prod\_Dyn + Prod\_Therm + Dissip + \frac{\partial ECT}{\partial t}$$

Boundary conditions are determined by the forcing layer and the suafec turbulent fluxes computed by Surfex

activation

- activation during PREP step :

```
&NAM_PREP_ISBA
        LISBA_CANOPY = T /
&NAM_PREP_TEB
        LTEB_CANOPY = T /
&NAM_PREP_WATFLUX
        LWAT_SBL = T /
&NAM_PREP_SEAFLUX
        LSEA_SBL = T /
```

- the model output is U, θ, q, TKE for the 6 extra-layers

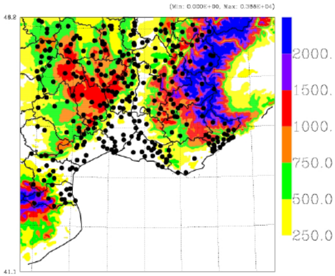
- T_{2m} is forecasted by the model and isn't diagnostic anymore
- surface fluxes are modified

validation of SBL in Arome

Use of SBL scheme above vegetation

Arome simulations

- south-east of France
- lower atm. 17m
- 5 extra-layers



validation of SBL with Arome

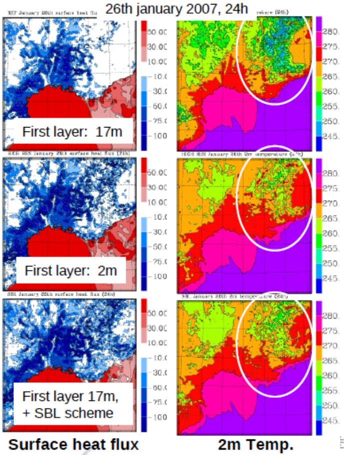
Masson and Seity, 2009, JAMC, 48, 7, 1377-1397

simulations Arome

- lower atm. layer 17m + veg. scheme
- lower atm. layer 2m + veg. scheme
- lower atm. layer 17m + veg. scheme + SBL

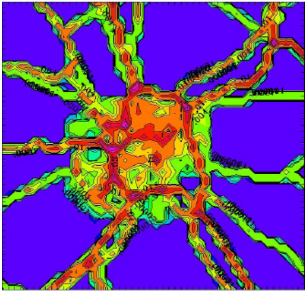
SBL is as good as high resolution

- better coupling sfc/atm at night
- sensible heat fluxes more negatives
- coherent temperature fields



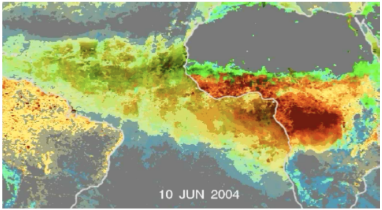
anthropic chemical emission

- independent of meteorological conditions : traffic, industrial activity
- emission cadastre : NOx fluxes over Toulouse



aerosols natural emission

- depends on meteorological conditions and surface properties
- desert aerosols, sea salt, biogenic fluxes

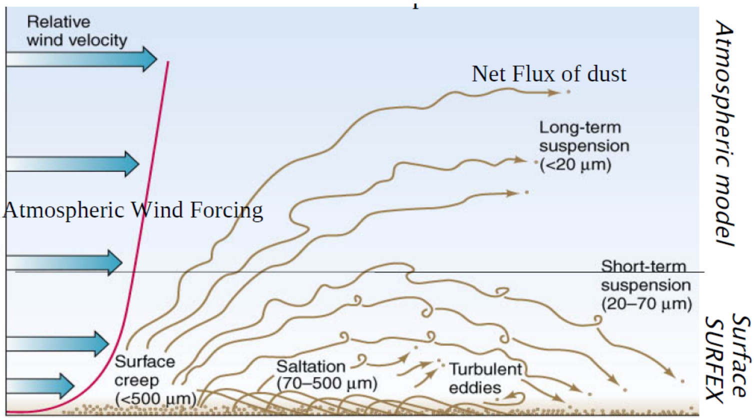


dust observed by MODIS

dust production

- threshold $u_* = 0.2m/s$
- saltation : horizontal mouvement of particules in a turbulent layer close to the surface
- sandblasting : bombardment of surface aggregates by particles in saltation and production of fines particules : desert aerosols

schematic diagram



DEAD model

modelling dust emissions

- computation of dry soil erosion threshold ${u_*}^d$ (fct of ρ, D, particules) Marticorena and Bergametti, 1995
- accounting for soil humidity :

$$w < w' \;:\; {u_*}^w = {u_*}^d$$

$$w > w' \;:\; {u_*}^w = {u_*}^d \cdot \left(1 + 1.21(w - w')^{0.68}\right)^{1/2}$$

w' depends on soil texture (%argile) Fecan et al., 1999

DEAD model

modelling dust emissions

- impact of roughness on ${u_*}^d$ Marticorena and Bergametti, 1995
- computation of the surface horizontal flux F_h : White, 1979
- computation of the dust vertical flux F_v :
  $F_v = \alpha \cdot F_h$ α depends on %argile

dry deposition

- parameterization of dry deposition for gaz and aerosols at surface by turbulent transfer
- gaz caracteristics to know : solubility, molecular mass
- parameterization of deposition with the deposition speed $v_d = -\frac{F_c}{c(z)}$

$$v_d = (R_a + R_b + R_c)^{-1}$$

R_a : aerodynamical resistance, R_b : quasi-laminar resistance et R_c surface resistance