Physical Parameterizations in Arpège-Aladin operational model

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Including corrections/contributions from Doina Banciu, Eric Bazile, Jean-François Geleyn, Jean-Marcel Piriou, Alfred Quinet, and several others.

Contents

Essential Notations

$\mathcal{A}$	advection part of the model
$A(\eta)$	implicit vertical coordinate definition array
A_g, A_n	ground albedo, snow albedo
$[]_a$	dry air
$[]_{\rm ad}$	non entraining moist adiabatic ascent
arg	soil clay fraction
$B(\eta)$	implicit vertical coordinate definition array
$B_\nu(\eta)$	black body Planck function
$[]_b$	layer bottom
$\mathcal{C}$	condensation
C_1, C_2, C_3	surface hydrous coefficients
C_M, C_H, C_{nM}, C_{nH}	surface exchange coefficients for momentum and heat, general and neutral case
C_T, C_G, C_V, C_N	thermal coefficient, for ground, vegetation, snow
C_w	hydraulic capacity $[m]$
c	sound speed; light speed
c_g	ground heat capacity
c_p, c_{pa}, c_{pv}	isobar specific heat, for dry air and vapour
c_w, c_i	specific heat of liquid water and of ice
CAPE	Convection Available Potential Energy
CIN	Convection Inhibition Energy
CVGQ	horizontal large scale moisture convergence
D_u, D_d	detrainment from updraught and downdraught
$\frac{D}{Dt}$	material derivative implying the advection by the mean (large scale) velocity
d_1, d_2	capacities of surface and deep reservoirs
$[]_d$	downdraught
$\mathcal{E}$	precipitation evaporation flux
E	surface evaporation
$E_{\rm kin}, E_{\rm pot}$	kinetic energy, potential energy
E_u, E_d	entrainment in updraught and downdraught
$e, e_{\rm sat}$	water vapour partial pressure and saturation value
F	evolution vertical fluxes
$\mathbf{F_b}$	buoyancy force
$F_{\rm cond}, F_{\rm cond\_i}, F_{\rm cond\_w}$	total condensation flux, solid and liquid part of it (under LCONDWT)
$F_{\rm dew}$	dew flux
$F_{\rm evg}$	bare ground evaporation flux
$F_{\rm evi}$	evaporation flux from surface ice reservoir
$F_{\rm evl}$	evaporation flux over water or moist soil
$F_{\rm evn}$	evaporation flux over snow or ice
$F_{\rm evr}$	evaporation flux from interception reservoir
$F_{\rm evv}$	evapo-transpiration flux
F_m	vertical mass flux
F_n	snow melting flux
$F_{\mathcal{P}}$	vertical mass flux associated to the precipitation flux
F_{pi}	deep soil freezing/melting flux
$F_q^{\rm cdif}$, $F_q^{\rm udif}$, $F_q^{\rm ddif}$	convective diffusion flux of moisture, updraught and downdraught contributions
$F_q^{\rm detr}$	moisture detrainment flux
$F_{\rm ror}, F_{\rm ros}, F_{\rm rop}$	runoffs from interception, surface, deep reservoirs
$F_s^{\rm cdif}$, $F_s^{\rm udif}$, $F_s^{\rm ddif}$	convective diffusion flux of dry static energy, updraught and downdraught contributions
F_{si}	surface freezing/melting flux
$F_{s\mathcal{P}}$	vertical dry static energy flux associated to the precipitation flux
F_{sp}^k	heat flux at underground level k
Fs_p	saturation fraction of the total reservoir
$F_{\rm tr}$	transpiration flux

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$F_{\mathbf{V}}$, $F_{\mathbf{V}}^{u}$, $F_{\mathbf{V}}^{d}$	convective diffusion flux of horizontal momentum, updraught and downdraught contributions
$F_{\nu}^{\downarrow}, F_{\nu}^{\uparrow}$	descending and ascending radiation fluxes at frequency ν
$F_{\psi}^{ps}, F_{\psi}^{pa}$	vertical flux of variable ψ associated to the pseudo subsidence and the pseudo ascent in the convection scheme.
$F_{\dagger}, F_{\odot}$	thermal and solar radiation fluxes
$F_{\odot\downarrow}, F_{\odot\uparrow}$	solar diffuse descending and ascending flux
$F_{\dagger\downarrow}, F_{\dagger\uparrow}$	thermal diffuse descending and ascending flux
$F_{\downarrow}^{*}, F_{\uparrow}^{*}$	difference between black body radiation and thermal diffuse descending and ascending flux
f	Coriolis parameter
f_V, f_H	Monin-Obukhov functions
$\mathcal{G}_u, \mathcal{G}_d$	Gregory-Kershaw coefficients
g	acceleration of gravity
$[]_G$	grid point location (semi-Lagrangian)
$\mathcal{H}$	normalized mountain height
H	effective obstacle height
H_0	diurnal wave e-folding depth
HU, HQ	Weighting coefficients respectively for saturating and air moisture in surface moisture computation
$\hbar$	(pseudo) enthalpy
h	Planck constant
$h = s + Lq$	moist static energy
h_s	standard deviation of unresolved orography
$[]_h$	top of the layer
I_b	Vertically integrated buoyancy based on a non entraining saturated adiabatic ascent from the lowest buoyant layer
I_ν	monochromatic radiation intensity
$[]_i$	ice
J	vertical turbulent diffusion flux
J_a	dry air vertical turbulent diffusion flux
J_h	moist static energy flux from the turbulent diffusion scheme
J_h^{meso}	enthalpy flux from the mesosphere
$J_q^{\mathrm{conv}}, J_s^{\mathrm{conv}}$	water vapour and dry static energy fluxes from the convective scheme
J_q or J_q^{turb}, J_s or J_s^{turb}, $J_{\mathbf{V}}$ or $J_{\mathbf{V}}^{\mathrm{turb}}$	water vapour, dry static energy and horizontal momentum fluxes from the turbulent diffusion scheme
J_v	water vapour vertical diffusion flux
$\mathcal{K}_{du}, \mathcal{K}_{dd}$	drag coefficients for prognostic updraught and downdraught
K	hydraulic conductivity
K_m, K_h, K_ψ	eddy exchange coefficients (momentum, heat, or any
K_u, K_d	detrainment rates
$\mathbf{k} = \mathbf{1}_z$	unit vector in upward direction
k	Boltzmann constant
$k_{\triangle\nu}$	absorption / diffusion optical depths
$k_{\nu\mathrm{abs}}, k_{\nu\mathrm{diff}}, k_{\nu\mathrm{emis}}, k_{\nu\mathrm{ext}}$	monochromatic radiation absorption, diffusion, emission, extinction coefficients
$[]_k$	iteration index; underground layer index
$\mathcal{L}$	Linear part of the model
L	Monin Obukhov length; latent heat; lift volumetric force
$L, \overline{L}, []_L, []_{\overline{L}}$	Lowest full model level and its lower interface
$L, L_v, L_{v-w}, L_{v-i}, L_{w-i}$	latent heats, condensation (generic), vaporisation, sublimation, melting
$l, \bar{l}, []_l, []_{\bar{l}}$	full model level, lower interface of model level
l_m, l_h	mixing lengths, for momentum and heat
ℓ	condensed water specific contents
ℓ_w, ℓ_i	liquid and solid water specific contents

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ℓ_s, ℓ_c	large scale ("stratiform") and subgrid ("convective") contributions to condensed water specific contents
$\ell_{\max}$	maximum sustainable water contents
$d\ell$	radiation path segment
lai	leaf area index
$\mathcal{M}$	Model
M_{detr}	total detrained moisture over the vertical
M_u, M_d	updraught and downdraught absolute mass fluxes
$[]_M$	medium point of semi-Lagrangian trajectory
$m = \frac{\partial \pi}{\partial \eta}$	vertical pressure divergence in η coordinate
$\mathcal{N}$	Non linear part of the model
N_e, N_w	Brunt-Väisälä frequency, based on θ_e and θ_w
N_s	surface Brunt-Väisälä frequency
n, n_s, n_c	total, large scale ("stratiform") and subgrid ("convective") cloudiness
$[]_O$	origin point of semi-Lagrangian trajectory
$\mathcal{P}, \mathcal{P}_s$, $\mathcal{P}_{\text{con}}$, $\mathcal{P}_{\text{LS}}$	precipitation flux, surface value, convective (subgrid) and large scale scheme parts
$\mathcal{P}_i$, $\mathcal{P}_w$	solid (snow) and liquid precipitation fluxes
$\hat{\mathcal{P}}$	non hydrostatic pressure departure
P_{ie}	fraction of the surface evaporating in ice phase
P_n, P_{nc}	fraction of the ground covered by snow, and value to use in thermal calculations
P_{ng}	cfr P_n, but possibly taking into account accumulation on the slopes
P_{nv}	snow fraction covering vegetation
P_{wsi}	ice fraction in the surface reservoir
p	true pressure ($p = \pi$ in hydrostatic model)
p_t, p_b	top and base pressure levels of an active cloud
$[]_p$	deep soil value; air parcel
$[]_{ps}, []_{pa}$	pseudo subsidence and pseudo ascent (so-called compensative subsidence and ascent)
Q	heat (flux)
Q_1, Q_2, Q_3	convective tendencies: sensible heating, latent heating, momentum tendency
$Q_{\text{lat}} = Q_{w\text{lat}} + Q_{i\text{lat}}$	surface latent heat flux (liquid water and ice)
Q_R	net radiative heating
Q_{sens}	surface sensible heat flux
q	specific moisture due to water vapour contents
q_a	dry air specific contents
$\triangle q_{\text{exc}}$	potential water vapour excess
q_w	wet bulb water vapour specific moisture
$\mathcal{R}$	moisture convergence modulation factor accounting for mesh size
$\mathcal{R}i$	Richardson number
R, R_a, R_v	perfect gas constant, for moist air, dry air and water vapour
$R_s, R_{s\min}, R_{s\max}$	surface resistance to water transfers
r	snow to water ratio; water vapour mixing ratio
RH	relative humidity
S_n	snow reservoir
S^0_ν	direct parallel radiation at frequency ν
S_ψ	source term in budget equation for ψ
$s = c_p T + \phi$	dry static energy
$[]_s$	surface value
$[]_{\text{sat}}$	saturation value
sab	soil sand fraction
T	temperature
T_d, T_w, T_v	dew point temperature, wet bulb temperature, virtual temperature
T_s, T_p	surface temperature, deep soil temperature
T_t	water triple point temperature
$t, \triangle t$	time, time step
U	projection of the altitude wind on the effective surface wind
u	wind zonal velocity
u_*	scaling velocity

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u_{fs}	zonal component of effective surface wind
u_s	see $\mathbf{v}_s$
$[]_u$	updraught
$\mathbf{V} = (u, v)$	horizontal wind
$\mathbf{v}_{fs}, \mathbf{v}_s$	effective surface wind – $\mathbf{v}_s$ in case of isotropic subgrid orography
$[]_v$	water vapour
veg, veg_a	vegetation fraction, part of it not covered by snow
veg_e	efficient vegetation fraction for convective precipitation
W	work; reservoir contents (kg/m^2)
$W_p, W_{p\,\max}$	(deep and) total reservoir contents and capacity
W_{pi}	total ice reservoir
$W_r, W_{r\,\max}$	interception reservoir contents and capacity
$W_s, W_{s\,\max}, W_{\mathrm{seq}}$	surface reservoir contents, capacity, equilibrium contents
W_{si}	surface ice reservoir
$w = \dot{z}$	vertical velocity in z coordinate
w	reservoir volumetric specific contents (m^3/m^3)
w_{fc}	deep reservoir volumetric contents at field capacity
$[]_w$	liquid water
x	zonal coordinate; reduced coordinate $x = z/H$ for soil depth
$\triangle x$	horizontal mesh size
$\triangle x_k$	underground layers thicknesses
y	meridian coordinate
Z	scale height for the decrease of the mixing length l_m
z	upwards metric (geopotential height) coordinate
z_0, z_{oH}	roughness length, heat roughness length
$z_{\mathbf{V}}, z_T$	PBL standard height for wind observation ($10m$) and temperature ($2m$).
α_{snow}	snow rate for convective precipitation partition
β	semi-implicit coefficient; diffusivity factor (radiation); GCVBETA
Γ_l	ratio of the turbulent vertical flux of horizontal momentum at level l to the flux at the surface (orographic drag).
γ	auxiliary variable, $c_{pv} - c_{w\|i}$, or R_a/cpa, see context
γ'	pseudo-mass coefficient
δ_{land}	land-sea mask (=1 on land)
δ_m	NDPSFI mass conservation option
δ_{stab}	stability indicator in PBL scheme
$\delta_{\mathrm{stab}}, \delta_{\mathrm{stab}}^{\downarrow}$	convective activity indicator, for updraught and downdraught
δ_ν	optical depth
$\delta^{\odot\downarrow}, \delta^{\odot\uparrow}$	optical thicknesses for the parallel descending and ascending (reflected) radiation fluxes
$\delta^{\dagger\downarrow}, \delta^{\dagger\uparrow}$	optical thicknesses for the thermal descending and ascending radiation fluxes
ϵ	emissivity; ratio R_a/R_v
$\epsilon_n, \epsilon_g, \epsilon_f$	emissivities of snow, bare ground and ground free of snow
η	hybrid vertical coordinate
θ	phase angle; zenithal angle
$\theta, \theta_e, \theta_w$	potential temperature, equivalent potential temperature, wet bulb potential temperature
κ	von Karmann constant
λ	wave length; thermal conductivity
λ_m, λ_h	asymptotic mixing length, for momentum and heat
λ_u, λ_d	entrainment rates for updraught and downdraught
μ	$\frac{R_v - R_a}{R_a}$; cinematic viscosity
$\mu = \cos\theta$	cosine of direct radiation zenithal angle
ν	wave frequency ; dynamic viscosity
ξ	(auxiliary variable)
π	hydrostatic pressure; π number
π_s	surface pressure
ρ, ρ_a, ρ_v	density, for dry air, for vapour
ρ_n	density of the snow
σ	Stefan Boltzmann constant

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$\sigma_c, \sigma_u, \sigma_d, \sigma_e$	convective mesh fraction, updraught, downdraught, environment
τ	transmissivity coefficient
$\tau = 86400s$	diurnal period
τ, τ_s	turbulent vertical flux of horizontal momentum, surface value
$\Phi(\psi), []_\Phi$	Physical part of the model
ϕ	geopotential; azimuthal angle
φ	latitude
ψ	relevant model variable
$\omega = \dot{\pi}$	vertical velocity in hydrostatic pressure coordinate
$\omega_0 = 2\pi/\tau$	diurnal pulsation
$\omega_c^* = \omega_c - \omega_e$	draught relative vertical velocity ;
$\omega_u, \omega_d, \omega_e$	(pressure) absolute vertical velocity for updraught, downdraught, environment
$\overset{\wedge}{\omega^*} = \sigma_u\omega_u^*,\ \overset{\vee}{\omega^*} = \sigma_d\omega_d^*$	updraught and downdraught relative mass fluxes
ϖ_ν	simple diffusion albedo
$\dagger$	long wave (earth) radiation
$\odot$	short wave (sun) radiation
$[]^0, []^+, []^-$	time t, $t + \triangle t$, $t - \triangle t$