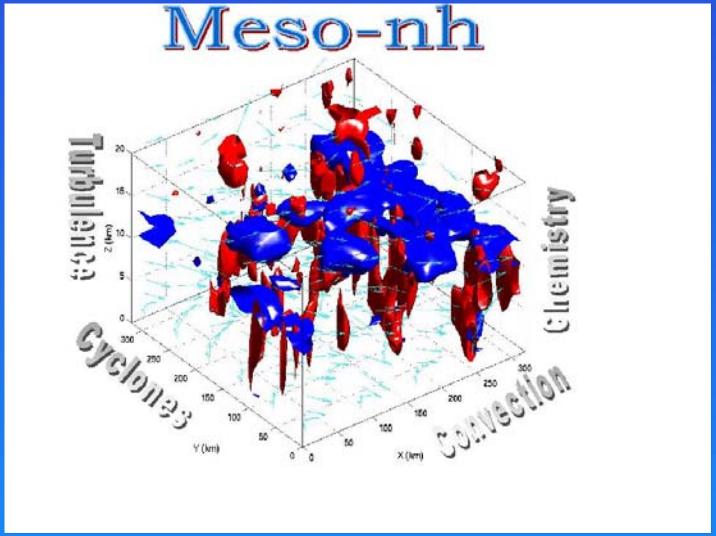
Generalities of Meso-NH physics that have to be known in AROME

Christine Lac, CNRM/GMME, Meteo-France



31 users' institutions

http://www.aero.obs-mip.fr/mesonh

1st AROME training course, Poina Brasov, November 21-25, 2005

PLAN

1. General characteristics of Meso-NH and common physics with AROME
2. Main practical differences Meso-NH/ALADIN-NH/AROME
3. Basic coding rules in Meso-NH

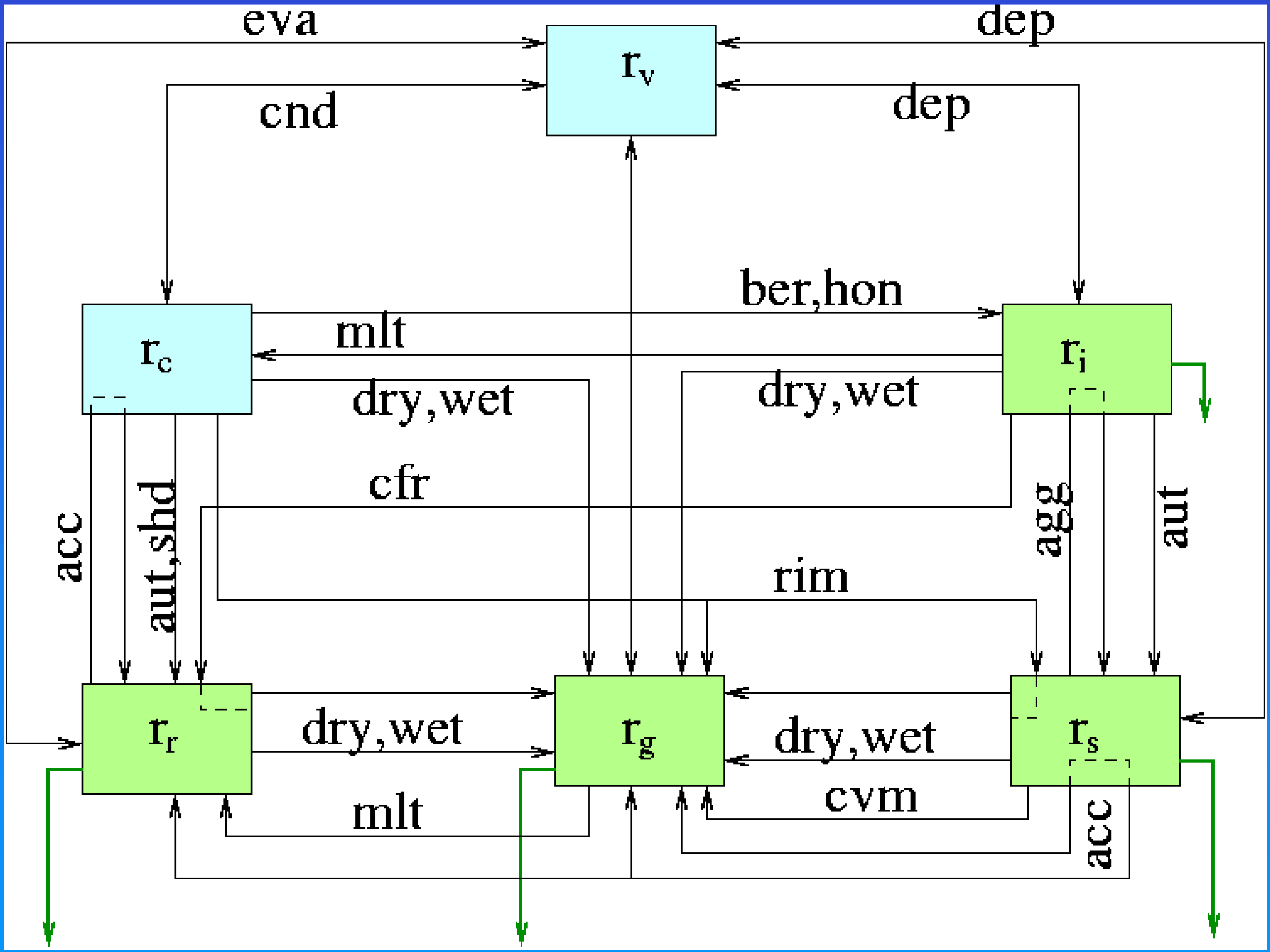
General description of Meso-NH

- Research model jointly developed by Meteo-France/GMME and Laboratoire d'Aerologie
- Large range of resolution from a few 10km resolution to LES
- Two-way nesting
- Ideal cases or real cases from ARPEGE, ALADIN or ECMWF
- Simulation 3D, 2D or 1D
- No assimilation
- Physics : Cloud resolving microphysics, 3D turbulence (TKE), externalised surface, shallow and deep convection, ECMWF radiation
- On-line chemistry (gazeous and aerosol (log-normal))
- Advanced diagnostics

Presentation of JP Pinty, Thursday morning

Microphysics

35 warm and cold processes for 6 hydrometeors



eva=evaporation
dep=vapor deposition
cnd=condensation
hen=heterogeneous nucleation
ber=Bergeron-Findeisen
hon=homogeneous nucleation
mlt=melting
dry,wet=dry and wet growth
acc=accretion
aut=atoconversion
shd=water shedding
cfr=contact freezing
agg=aggregation
rim=riming
cvm=conversion melting

Presentation of S.Malardel, this morning

Turbulence

A prognostic equation for the TKE, e, while all the other 2nd order moments are diagnosed:

$$\frac{\partial e}{\partial t} = \underbrace{-\frac{1}{\rho}\frac{\partial(\rho \overline{u_i} e)}{\partial x_i}}_{Advection} \underbrace{-\overline{u'_i u'_j}\frac{\partial \overline{u_i}}{\partial x_j}}_{Dynamic} + \underbrace{\frac{g}{\theta_{vref}}\overline{w'\theta_v'}}_{Thermic} + \underbrace{\frac{1}{\rho_{ref}}\frac{\partial}{\partial x_i} C\rho_{ref} L\sqrt{e}\frac{\partial e}{\partial x_i}}_{Diffusion} \underbrace{-C_\varepsilon \frac{e^{3/2}}{L}}_{Dissipation\ \varepsilon}$$

$$\overline{w'\theta'} = -\frac{2}{3}\frac{L}{C_{p\theta}}\sqrt{e}\Phi_3 \frac{\partial \overline{\theta}}{\partial z}$$

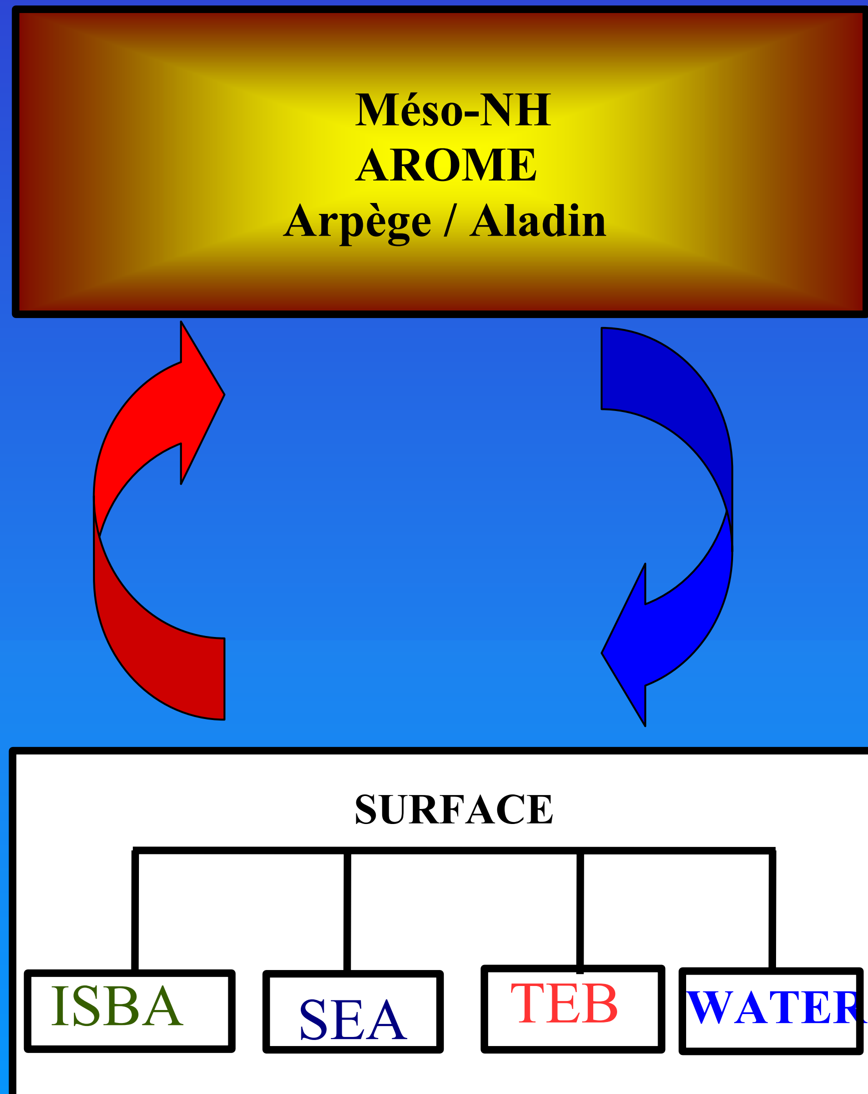
3rd order moments (TOM) are neglected

Closure through the mixing-length L : Bougeault-Lacarrère for AROME

- Méso-NH : Horizontal exchanges in 3D turbulence
  - Horizontal derivatives (« Shuman » operator)
  - Computation of slope orthogonal wind
- ALADIN : - « Column » physics
  - Horizontal derivatives only computed in spectral space
- AROME : 1D version of the 3D Meso-NH scheme

Presentation of P.Le Moigne, just after

Externalised surface



albedo
emissivity
radiative temperature

Momentum, heat, water vapor, CO2, chemical fluxes

Atmospheric forcing
Sun position
radiative fluxes

Dynamic equations

Méso-NH

Anelastic with 3 possible formulations : LH, MAE and **DUR**

$$\vec{\nabla}.(\rho_{ref}\vec{U}) = 0, \quad \rho_{ref}(z), \frac{\partial \rho_{ref}}{\partial t} = 0$$

$\rightarrow$ Z-type

Pressure by solving continuity equation (p diagnostic)

ALADIN-NH/AROME

Fully Compressible

$\rightarrow$ P-type

Continuity equation

Numerical schemes

Méso-NH

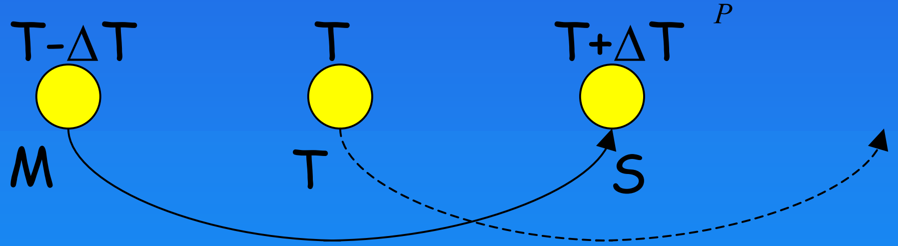
• Advection : 2nd order difference eulerian schemes, positive definite :

FCT or MPDATA

• Explicite temporal scheme – Leap-frog

$$\frac{\partial}{\partial t}(\rho_{ref} X) = \sum_P S_P, \quad p : processes$$

$$\rho_{ref} X(t+\Delta t) = \rho_{ref} X(t-\Delta t) + 2\Delta t \sum_P S_P(t)$$



M and T are kept every Δt

The cost wasn't a necessity at the beginning !
The most precise but also the most unstable : but the Courant number determine the stability on the gravity wave speed (10km$\rightarrow$20s, 2km $\rightarrow$4s)

For the first Δt, forward lateral temporal centred scheme (unstable)

ALADIN-NH/AROME

• Advection : Semi-lagrangian

• Semi-implicite temporal scheme

Fluxes or tendencies ?

Méso-NH

Tendencies are added step by step to the $(t+\Delta t)$ fields after each process

$$X_S = X_M + \delta X_{ADV}(X_T) + \delta X_{CONV}(X_T) + \delta X_{TURB}(X_M) + \delta X_{MICRO}(X_T)$$

AROME

- Current state : Do not use the « conservative » flux form of the equations but use direct tendencies from Méso-NH parameterization outputs

ALADIN-NH

- Output of parameterizations = fluxes
- Tendencies are computed at the end of the physics with « conservative » equations in flux divergence form.

Time step organization : Adjustment to saturation

Méso-NH

The microphysics is divided in two parts :
-the « slow » terms (sedimentation, accretion, autoconversion ...) : explicit sources
- the « fast » terms (adjustment to saturation) : implicit

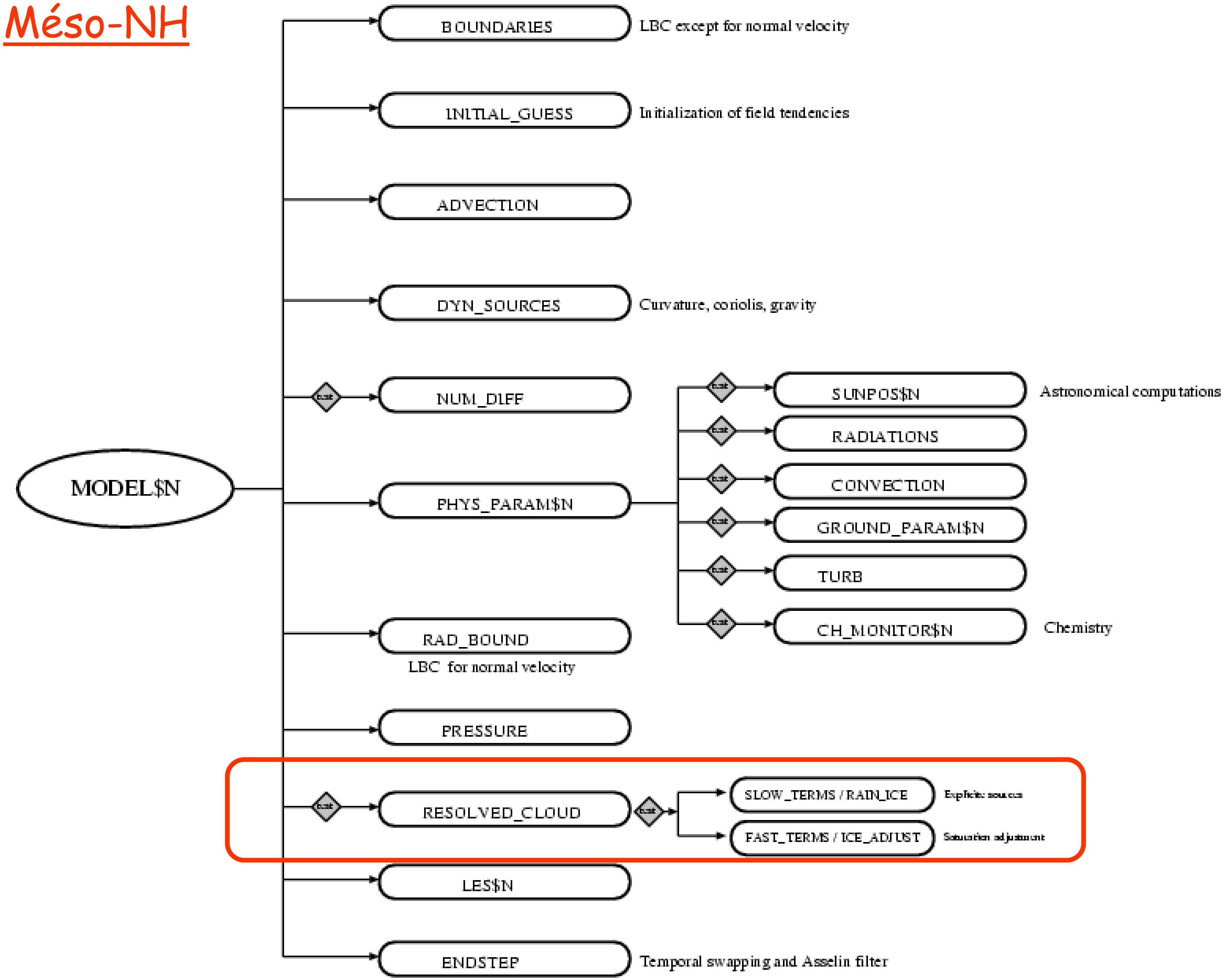
The adjustment is the last process of the time step.

ALADIN-NH

The last processes of the time step are the spectral computations, the last process of the grid point computations is the first half of the SI.

Structure of the temporal loop

Méso-NH



AROME

Grid point space

Spectral space

Inverse transforms

Temporal swapping

- Adjustment
- Temporal swapping for the physics
- Physics (with slow terms)
- Interpolation SL
- Other dynamical tendencies
- SI (1st part)

Direct transforms

- SI (2nd part) Diffusion

State variables

Méso-NH

U, V, W, θ, r_v, r_c, r_r, r_i, r_s, r_g, TKE, scalar variables on C-grid, on horizontal and vertical

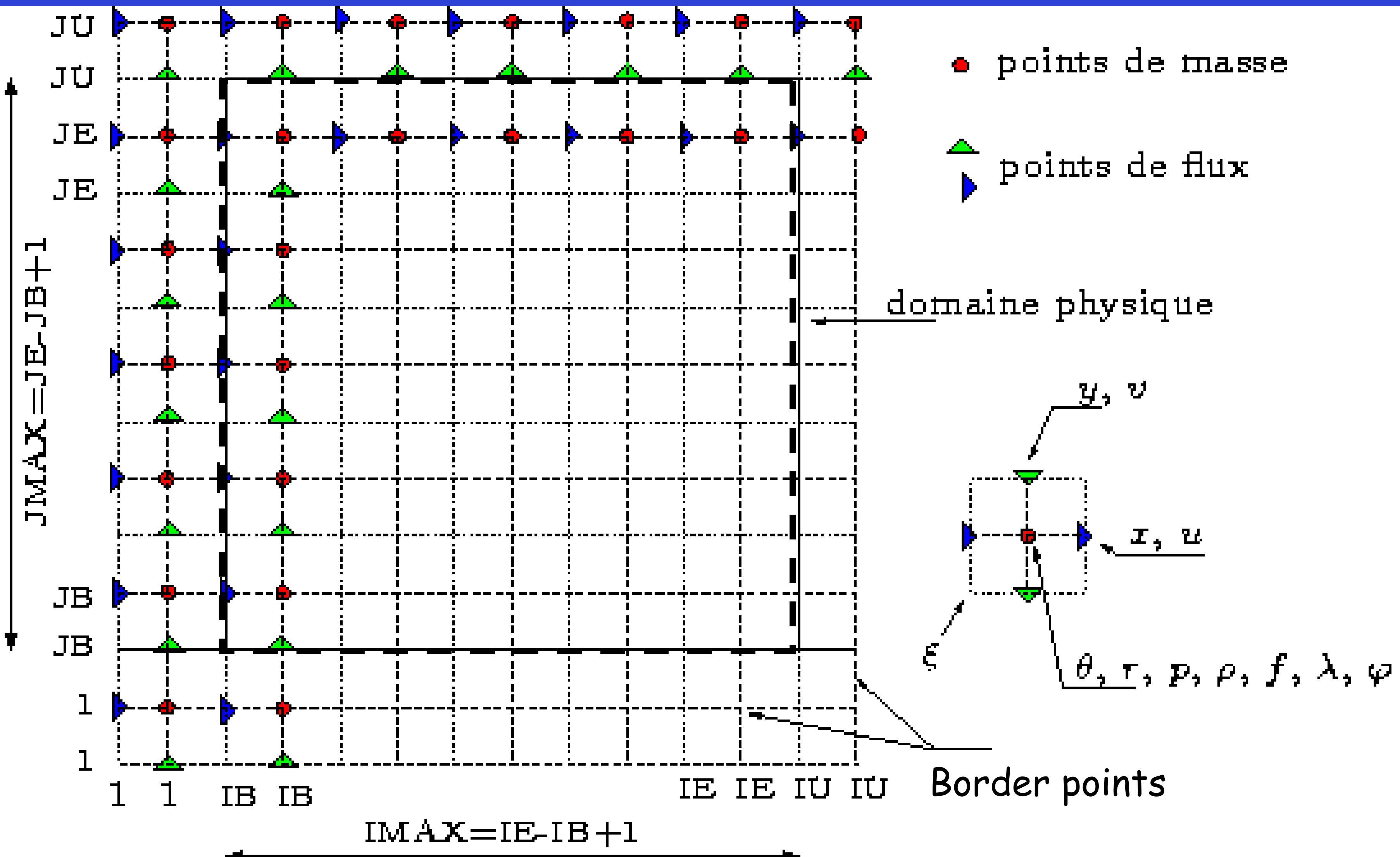
ALADIN-NH

U, V, d_4, T, q_v ($+q_l$, q_i), P on A-grid

AROME

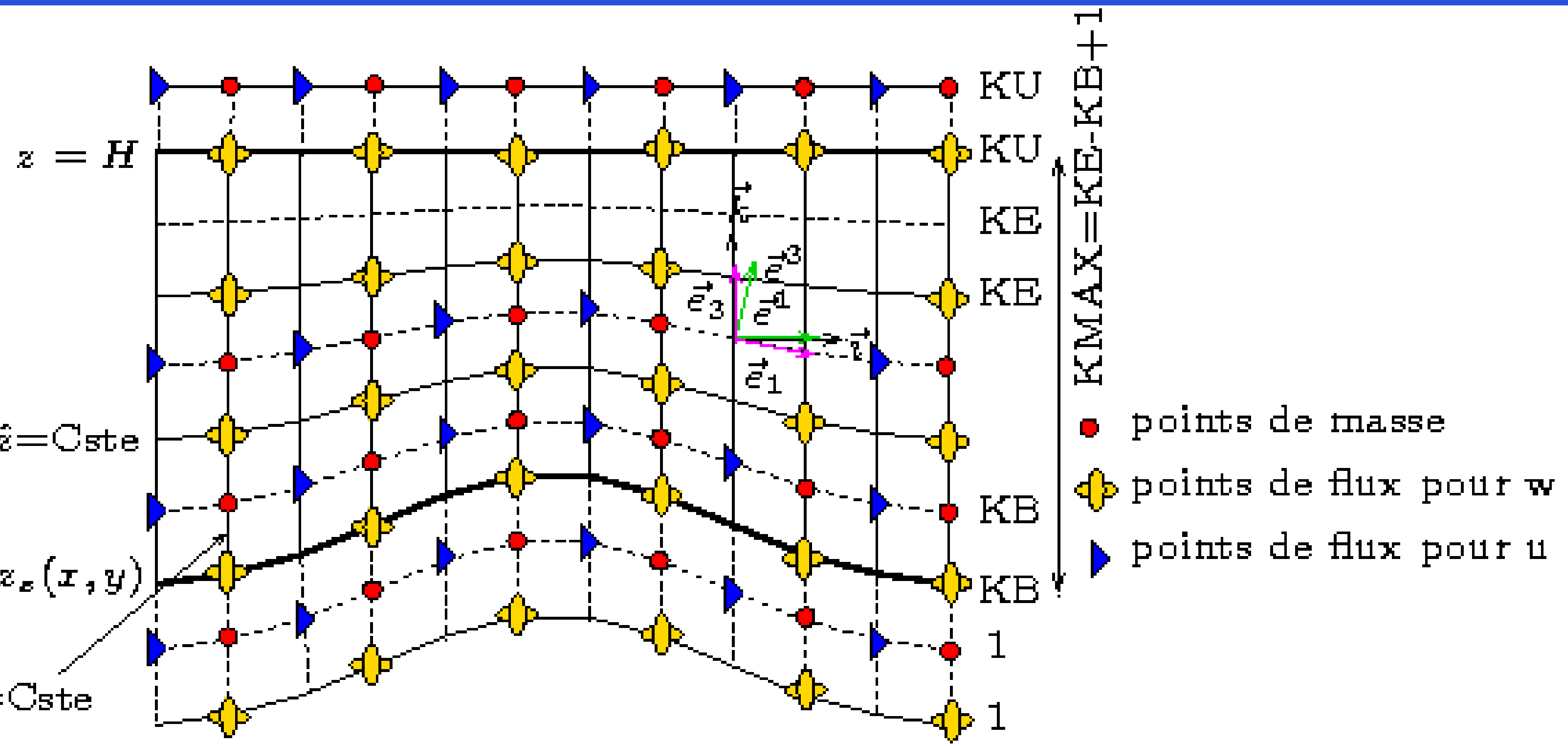
- The GFL structure allows to easily add new variables in the code
- Conversion from ALADIN variables to Méso-NH and from tendencies of Méso-NH to tendencies of ALADIN
- Computation of z from the geopotential ϕ every Δt
- Neutralization of « flux point » to « mass point » operators in turbulence scheme

Horizontally



Gal Chen et Sommerville vertical coordinate

$$\hat{z} = \frac{z - z_s}{H - z_s} H$$



Diagnostics

Méso-NH

• Budget analysis based on the processes, step by step storage of the source terms. Possibility of time and spatial (cartesian and masks) means.

• Temporal evolution of spatial means of variables

• Tracking of aircraft, balloons …

• Post-processing diagnostics

ALADIN-NH

Diagnostics in the grid-point space, after the physics based on the flux form. Possibility of time and spatial means.

AROME

Will be an adaptation of the flux form equations (like in ALADIN) to the explicit physics

Coding standards in Meso-NH

- External documentation : Scientific + User's guide
- Internal documentation : Header and section comments
- Current code framework : Fortran 90
- Data MODULES : To export ressources (variables, constants …) to other units (routines, other modules, main program)

  The instruction *USE name_of_the_module* appears at the beginning of the declarations of the procedure.

  - MODD_ : Declaration of variables

    ex: MODD_FIELDn include prognostic variables (XUT, XVT, XWT…)
  - MODN_ : Declaration of namelists

    ex: MODN_CONF include the declaration of the Namelist &NAM_CONF
  - MODE_ : Executing functions or routines

    ex: MODE_THERMO include the calculation of the saturation vapor
  - MODI_ : Interface of the routine

Coding standards in Meso-NH

- DOCTOR naming convention :

Type	INTEGER	REAL	LOGICAL	CHARACT
Global or MODULE	N	X	L	C
Dummy arguments	K	P	O	H
Local variables	I	Z	G	Y

Due to distributed memory machines :
-local : their value differs between processors
- global : their value is the same on all processors

IMPLICIT NONE statement is mandatory: improves portability

Coding standards in Meso-NH

- Discrete operators :

$Ex: \quad \rho_{ref}\vec{\nabla}\Phi'$: Source term in the W equation

$$\underbrace{MZM(PRHODJ)}_{\substack{Shuman\ operator \\ USE\ MODI\_SHUMAN}} * \underbrace{GZ\_M\_W}_{\substack{Cartesian\ gradient\ operator \\ USE\ MODI\_GRADIENT\_}} (ZPHIT, ZDZZ)$$

<u>First letter</u> : D for finite difference operator, M for mean operator
<u>Second letter</u> : X for the direction x, Y and Z
<u>Third letter</u> : M for mass point, F for flux point

$$MZM \rightarrow \overline{\alpha}^{z} \ for\ \alpha\ at\ mass$$

$$GZ\_M\_ \rightarrow \frac{\partial \alpha}{\partial z} \ for\ \alpha\ at\ mass$$

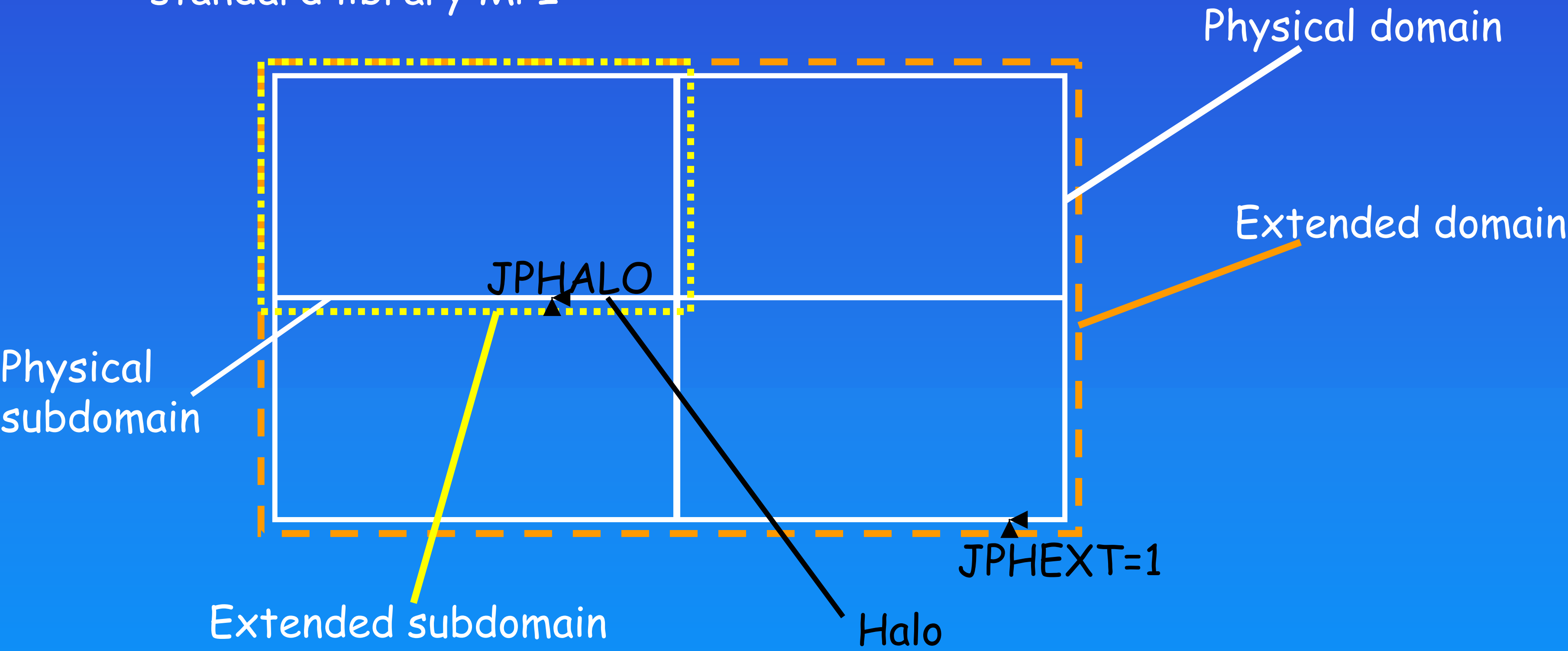
Coding standards in Meso-NH

Parallelization for distributed memory computers :

Decomposition of *m* horizontally nested models on *n* processors

Constraint : Full compatibility between 1 and n processors

→ Parallelization routines included in an interface library based on the standard library MPI



AROME : Neutralization of the splitting by :

$(i,j,k) \rightarrow (N,1,k')$ with N_{max}=NPROMA JPHALO=0

Management of the code Meso-NH

Management by GMME/Meso-NH and LA :

-Unix procedures and Makefile
- Code on RCS and CVS :
    Masdev for evolution, Bugfix for correction :
    Current version : Masdev4_6 bug3
- Output files : FM (binary)
- Meso-NH tools : Conversion to GRIB, Netcdf, Vis5D
- Graphic package (NCAR graphics)

Contact point for the phasing in Meso-NH :
christine.lac@meteo.fr
As for SURFEX : patrick.lemoigne@meteo.fr
Changes in the physics in AROME are updated in the following version of Meso-NH