Seconda parte (5-9-2011)

Definizione dei termini ‘K’

Sia ψ una quantità trasportata dal moto:

$$\partial_t \psi = K_\psi \quad = \quad -\frac{1}{\rho}\partial_z(\Phi)$$

$$\Phi = -\rho K \partial_z \psi$$

$$\Phi_S = -\rho_S C_D(\psi_{NLEV} - \psi_S)$$

Φ Flusso turbolento (positivo se ‘upward’)

Φ_S flusso turbolento al suolo

Chiusura E-*l*:

$$K = l_m \sqrt{C_E \overline{E}}$$

l_m mixing length: stable -> Blackadar modified
unstable -> Bougeault 1986 (modified)

$$u = \overline{u} + u', \qquad v = \overline{v} + v', \qquad w = \overline{w} + w', \quad \psi = \overline{\psi} + \psi', \qquad P', \rho' \approx 0$$

$$\overline{E} = \frac{1}{2}\left(\overline{u'u'} + \overline{v'v'} + \overline{w'w'}\right)$$

Equazione per l'energia cinetica turbolenta

$$\frac{d\overline{E}}{dt} = K_E - \overline{u_i' u_j'} \frac{\partial \overline{u_i}}{\partial x_j} + \frac{g}{\overline{\theta}_V} \overline{w' \theta'_V} - \varepsilon$$

Ipotesi sul termine dissipativo:

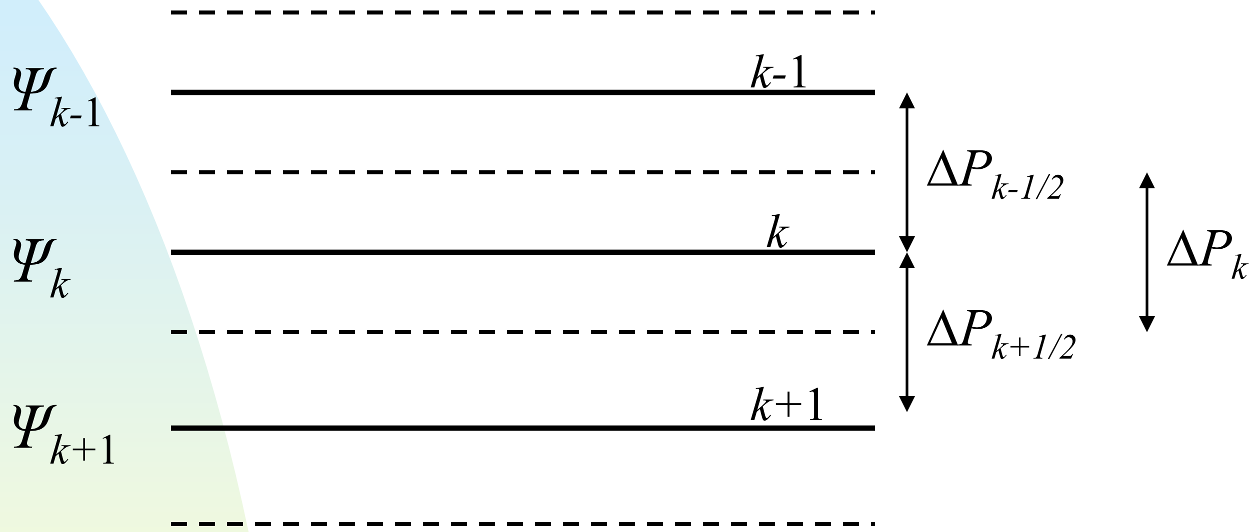
$$\varepsilon = \frac{1}{l_m} \left(\sqrt{C_E \overline{E}} \right)^3$$

Closure hypothesis: Turbulent fluxes of a scalar quantity

$$\begin{matrix} \overline{u'\psi'} \\ \overline{v'\psi'} \\ \overline{w'\psi'} \end{matrix} = -K\,\vec{\nabla}\,\overline{\psi}$$

Closure hypothesis: Turbulent fluxes of a vector field

$$\overline{u_i'u_j'} = \frac{2}{3}\delta_{ij}\overline{E} - K\left(\frac{\partial\,\overline{u}_i}{\partial x_j} + \frac{\partial\,\overline{u}_j}{\partial x_i}\right)$$



Ψ_{k-1}
k-1
$\Delta P_{k-1/2}$
Ψ_k
k
ΔP_k
$\Delta P_{k+1/2}$
Ψ_{k+1}
k+1

Schema ‘backward’ implicito

$$\psi_k^{n+1} = \psi_k^n - c_k\left(\psi_{k+1}^{n+1} - \psi_k^{n+1}\right) + a_k\left(\psi_k^{n+1} - \psi_{k-1}^{n+1}\right)$$

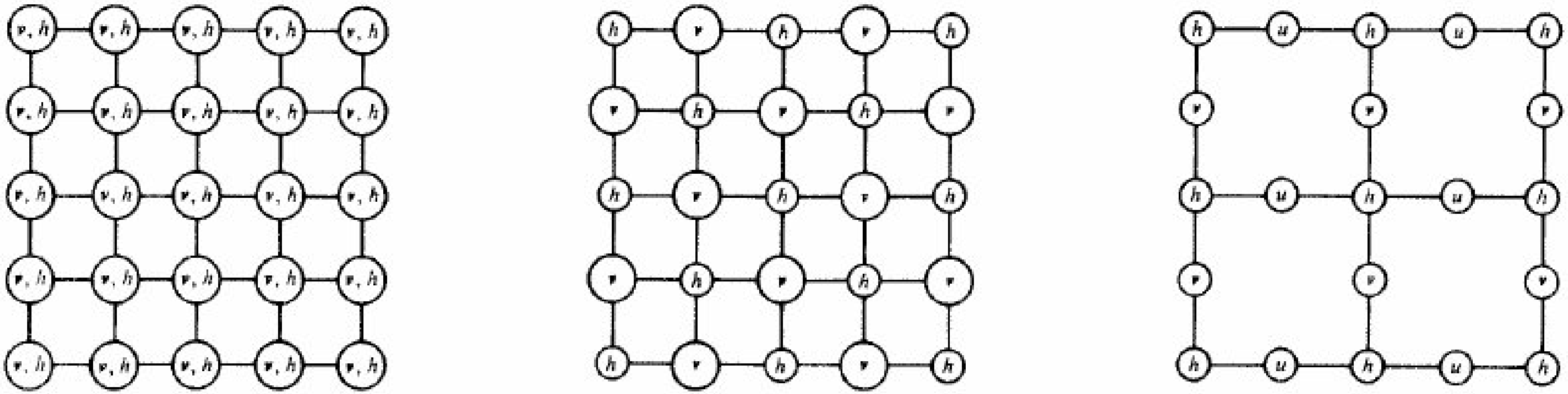
$$c_k = -\frac{\Delta t\ g^2 \Delta P_{k+\frac{1}{2}} \mathrm{K}_{k+\frac{1}{2}}}{\Delta P_k \Delta\Phi^2_{k+\frac{1}{2}}}, \quad k = NTOP, \ldots., NLEV - 1$$

$$a_k = -\frac{\Delta t\ g^2 \Delta P_{k-\frac{1}{2}} \mathrm{K}_{k-\frac{1}{2}}}{\Delta P_k \Delta\Phi^2_{k-\frac{1}{2}}}$$

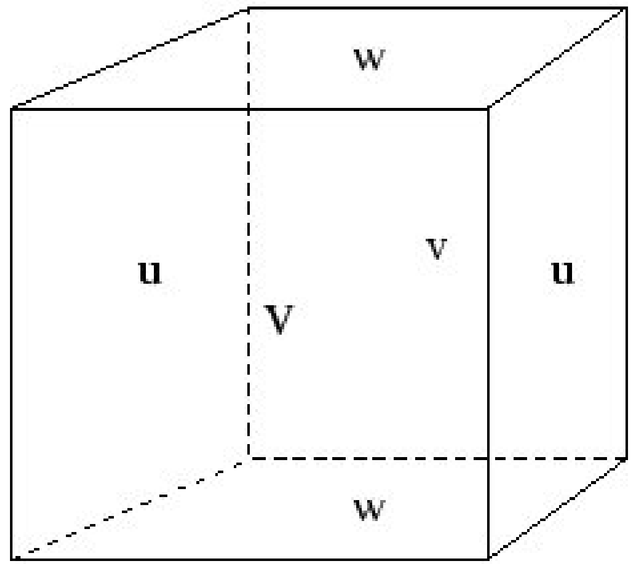
$$a_k \psi_{k-1}^{n+1} + \left(1 - a_k - c_k\right)\psi_k^{n+1} + c_k \psi_{k+1}^{n+1} = \psi_k^n$$

Discretizzazione orizzontale

(A) (E) (C)



Discretizzazione verticale ('Lorenz')



Three dimensional staggering of velocity components. This facilitates the natural discretization of the continuity and tracer equations.

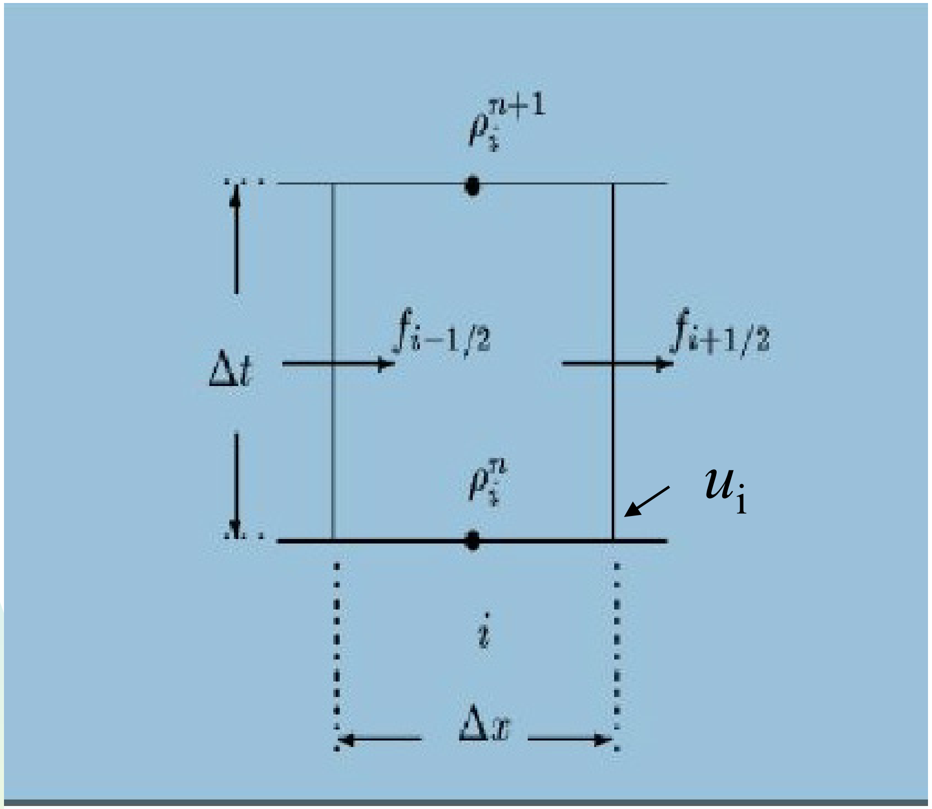
Schema di avvezione 'WAF'

Toro, E.F. *A Weighted Average Flux method for hyperbolic conservation laws.* Proc. Roy. Soc. Lond. A 423, pp 401-418, 1989.

Toro, E.F. *The Weighted Average Flux method applied to the Euler equation.* Phil. Trans. R. Soc. Lond. A 341, pp 499-500, 1992.

Godunov, S.K.,*A difference scheme for numerical computation of discontinuous solution of hydrodinamic equation*, Math. Sbornik, 47, pp 271-306, in Russian, Translated US Joint Publ. Res. Serv. JPRS 7226 (1969), 1959.

$$\frac{\partial \rho}{\partial t} + \frac{\partial (\rho u)}{\partial x} = 0$$



$$f = \rho u$$

$$\rho_i^{n+1} = \rho_i^n - \frac{\Delta t}{\Delta x}(f_{i+1/2} - f_{i-1/2}) = 0$$

‘WAF limiter’ :

$$f_{i+1/2} = \frac{1}{2}(1+\phi)u_i\rho_i^n + \frac{1}{2}(1-\phi)u_i\rho_{i+1}^n$$

$$\phi = \phi(c, r)$$

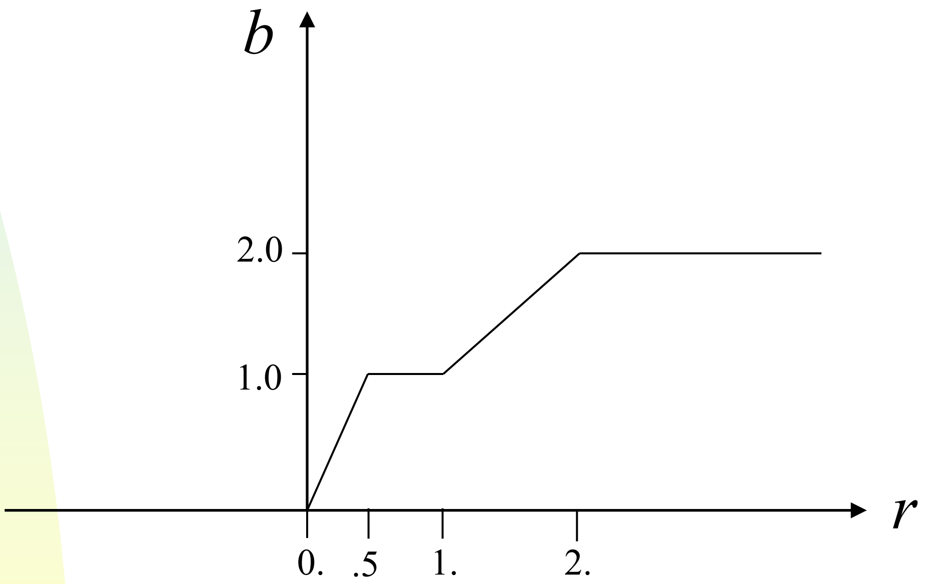
$$c = u_i \frac{\Delta t}{\Delta x}$$

$$r = {(\rho_i^n - \rho_{i-1}^n)}\Big/{(\rho_{i+1}^n - \rho_i^n)}, \quad c \geq 0$$

$$r = {(\rho_{i+2}^n - \rho_{i+1}^n)}\Big/{(\rho_{i+1}^n - \rho_i^n)}, \quad c \leq 0$$

$$\phi_{i+1/2} = \operatorname{sgn}(c)\left[1 + (|c| - 1)b(r)\right]$$

$$b(r) = \quad \max(0, \min(2r,1), \min(r,2))$$



3D WAF in coordinate sferiche:

Hubbard and Nikiforakis, 2003:
'A three-dimensional adaptive, Godunov type model for global atmospheric flows I: tracer advection on fixed grids'.
Monthly Weather Review, **131**, 1848-1864.

$$\frac{\partial \rho}{\partial t} + \vec{V} \bullet \vec{\nabla} \rho = 0$$

$$\frac{\partial \rho}{\partial t} = -\vec{\nabla}(\rho \vec{V}) + \rho \vec{\nabla} \bullet \vec{V}$$

Schema temporale ‘time splitted’ che conserva la massa

$$\rho^{*} = \rho^{n} - \Delta t \frac{\partial(\rho^{n}\dot{\sigma})}{\partial\sigma} + \rho^{n}\frac{\partial\dot{\sigma}}{\partial\sigma}$$

$$\rho^{**} = \rho^{*} - \Delta t \frac{\partial(\rho^{*}v)}{\partial y} + \rho^{n}\frac{\partial v}{\partial y}$$

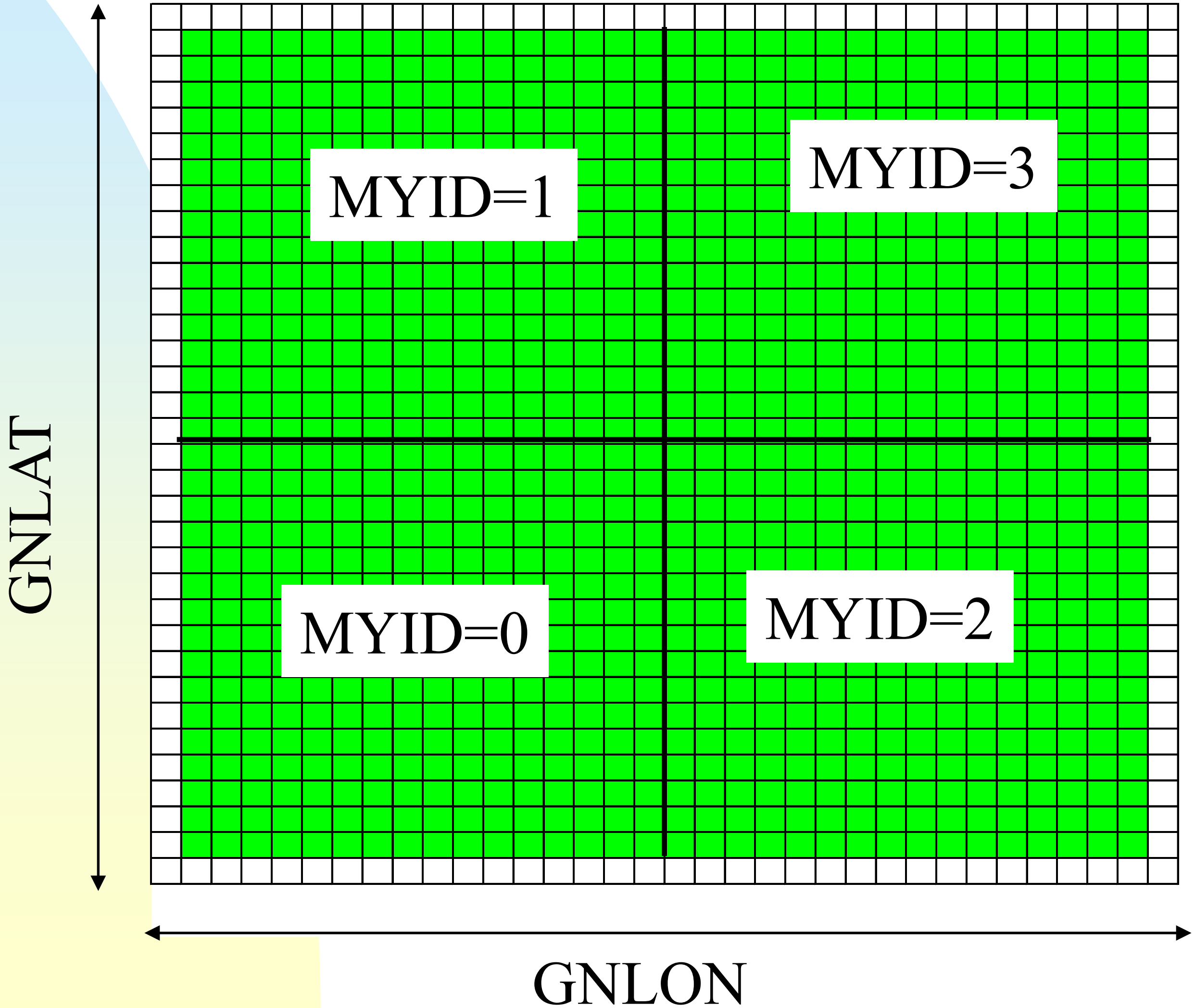
$$\rho^{n+1} = \rho^{**} - \Delta t \frac{\partial(\rho^{**}u)}{\partial x} + \rho^{n}\frac{\partial u}{\partial x}$$

Schema temporale generale di Bolam

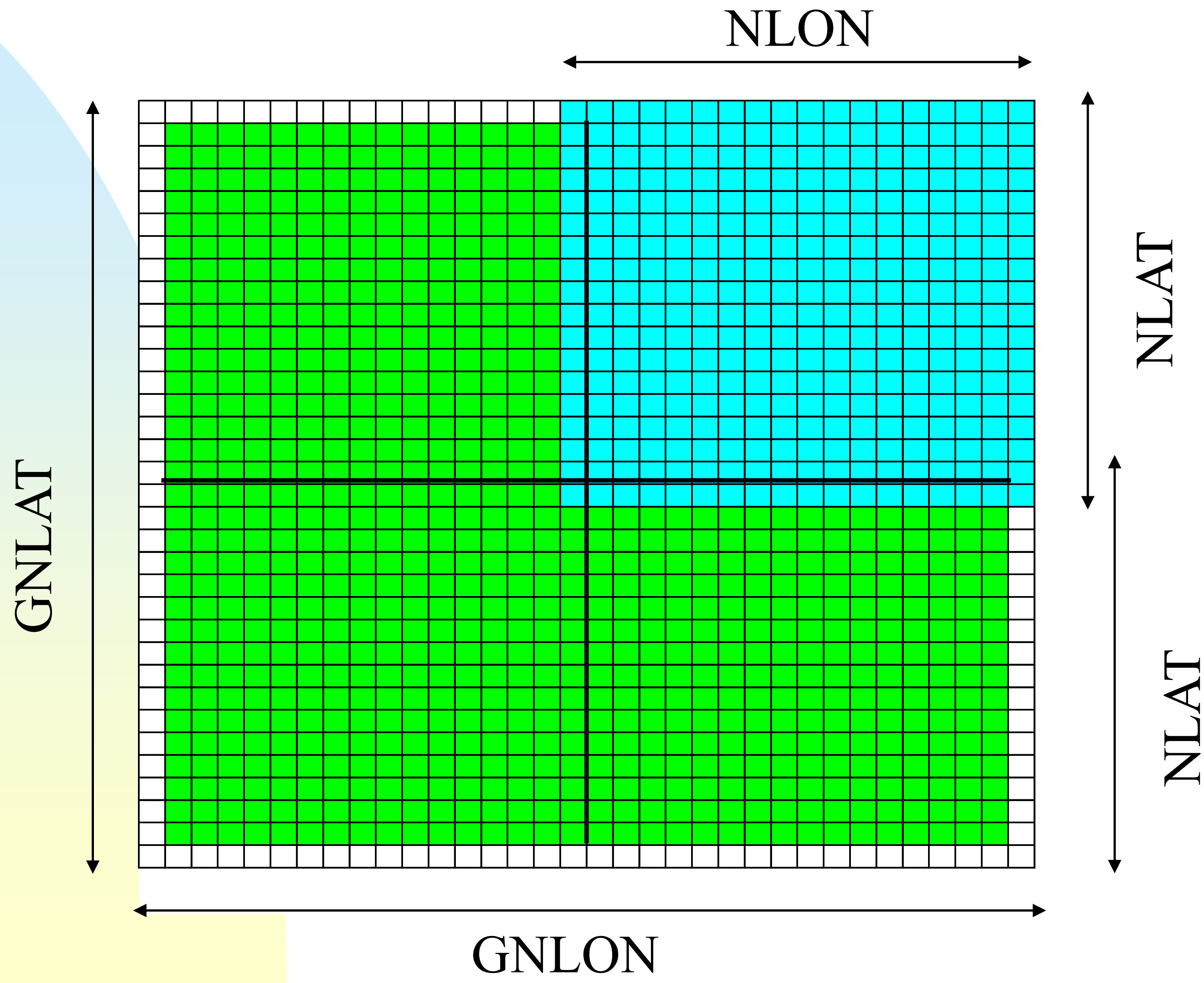
- Time split
- ‘forward backward’ per la parte di onde di gravità (timestep DTSTEP/4)
- Avvezioni (timestep DTSTEP)
- Fisica (timestep DTSTEP)
- Rilassamento alle condizioni al contorno

Parallelismo di Bolam

'Domain decomposition'



Per facilitare il calcolo delle derivate si introduce una 'ghostline' per ogni sottodominio



NPROCSX, NPROCSY

NLON=(GNLON-2)/NPROCSX+2

NLAT=(GNLAT-2)/NPROCSY+2

GNLON=(NLON-2)*NPROCSX+2

GNLAT=(NLAT-2)*NPROCSY+2

(NLON e NLAT numeri pari)

‘Speedup’ della versione parallela

- Dipende dall’architettura della macchina
- Dipende dalla possibilità di utilizzare hyper-threading (two virtual processes for each processor core)
- Dipende da come si ‘spalma’ il dominio fisico sui processori
- Mediamente con 16 processi uno speedup di 8 volte
- Tende a saturare per numero elevato di processi (>100)