Which multiphasic equations for a general physics/dynamics interface ?

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25 novembre 2008

Why multiphasic equations are important at mesoscale ?

To resolve the deep convection, we need

- a « convective » $\overline{w}$
- a realistic parametrisation of water phase changes and microphysical processes (also for ice)
- a correct representation of the interaction of the water cycle with the mass, momentum and energy budget (impact of hydrometeors on pressure, inertia, weight, latent heat release …)

Multiphasic pronostic variables

Local multiphasic variables

The « fluid » described by the model equations is a complex mixture of gaz (dry air + vapor) + hydrométéors (+ chemicals, aerosols ...).

Grid scale multiphasic variables

In the model, the pronosctic variables are reprensative of an averaged value for each grid element.

For any state variable ψ

$$\psi_a, \psi_v, \psi_c, \psi_i, \psi_r, \psi_s, \psi_g \ldots \quad \underbrace{\Rightarrow}_{\textit{multiphasic}} \quad \psi, \tilde{\psi}_k \quad \underbrace{\Rightarrow}_{\textit{gridscale}} \quad \overline{\psi}, \psi'$$

Example 1 : the perfect gaz equation

Which p, which R, which ρ ?

$$\overline{p} = \overline{\rho} R \overline{T}$$

$$p = p_a + p_v = \rho_a R_a T + \rho_v R_v T = \rho R T$$

where :

- $\rho = \sum_k q_k \rho_k$ with $q_k = \rho_k / \rho_t$
- $R = q_a R_a + q_v R_v = R_a - q_v (R_v - R_a) - (q_c + q_i + q_r + q_s + q_g) R_a$
- T is the temperature of the multiphasic system supposed in instantaneous thermodynamics equilibrium

Example 2.1 : the momentum equation - Barycentric formulation

Which u, v, w ?

- u and v are the same for all the species
- $w = \sum_k \rho_k w_k$, w_k depends on the precipitation velocity of the specie k
- $\tilde{w}_k$ is the departure with respect to the barycentric vertical velocity $\Rightarrow$ new advection terms (computed in the phys/dyn interface ?)

Example 2.2 : the momentum equation - The pressure force

Discretisation of the pressure force

$$\vec{grad}(RT) = \vec{grad}_h(R_a T_v)$$

with

$$T_v = \left(1 - (\frac{R_v}{R_a} - 1)q_v - (q_c + q_r + q_i + q_s + q_g)\right) T$$

T or T_v in spectral space (LSPRT)

- T and q_v in spectral space

$$\vec{grad}(RT) = R\vec{grad}(T) + (R_v - Ra)\vec{grad}(q_v)T$$

Incorrect formulation for a mutiphasic system (but $\vec{grad}(q_k), k \neq v$ are usually not available because the hydrometeors are not going in spectral space)

- T_v in spectral space

$$\vec{grad}(RT) = R\vec{grad}(T_v)$$

Example 3 : the continuity equation

The « forgotten » DR/Dt

Expressing ρ as $p/(RT)$ in the continuity equation gives :

$$\frac{Dp}{Dt} - \frac{p}{R}\frac{DR}{Dt} - \frac{p}{T}\frac{DT}{Dt} = -pD_3$$

For the time being, the term DR/Dt is not coded in Arome. It is a « mass » term which should exist in an adiabatic run starting with «analysed » hydrometeors.

Physics or dynamics ?

DR/Dt computed in the phys/dyn interface ?

Example 4.1 : the energy/thermodynamics equation - latent heat terms

$$c_p \frac{DT}{Dt} - \frac{RT}{p}\frac{Dp}{Dt} = \mathcal{Q}$$

where

$$\mathcal{Q} = \mathrm{div}(c_p \overline{\rho T' \vec{u}'}) + \epsilon + \mathrm{div}\vec{J}_Q + L_v(T)\dot{q}_{liq} + L_i(T)\dot{q}_{sol}$$

$$\frac{D c_p T}{Dt} - \frac{RT}{p}\frac{Dp}{Dt} = \mathcal{Q}_o$$

where

$$\mathcal{Q}_o = \mathrm{div}(c_p \overline{\rho T' \vec{u}'}) + \epsilon + \mathrm{div}\vec{J}_Q + L_v(T=0)\dot{q}_{liq} + L_i(T=0)\dot{q}_{sol}$$

The way we compute the dynamics and the way we compute the physics have to be coherent.

Example 4.2 : the energy/thermodynamics equation - KE/PE/IE conversions

How to take into account the subgrid part of the « conversion » term (DP/Dt term in the thermodynamics equation)

- In a z-coordinate model

$$\frac{\partial \overline{w'\theta'}}{\partial z} \Longrightarrow \frac{\partial T}{\partial t}$$

- In a mass-coordinate model ($s = c_p T + \phi$)

$$\frac{\partial \overline{w's'}}{\partial z} - \frac{\partial KE}{\partial t} \Longrightarrow \frac{\partial T}{\partial t}$$

Open question discussed tomorrow at 1600. Everybody is welcome.....

Is the design of a general phys/dyn interface an utopian project ?