Dynamics status and plans

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PL on dynamics

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Overview

- VFE discretization for the NH version of HARMONIE
- Non-constant linearized map-factor for large areas
- Frequent update of lateral boundaries
- Transparent lateral boundary conditions
- Dynamics-physics interface
- Conservative semi-Lagrangian advection
- Semi-elastic model as alternative to NH

Vertical Finite Element discretization

Prognostic model equations

$$\frac{d}{dt}\mathbf{V} + \frac{RT}{p}\nabla_\eta p + \left(\frac{1}{m}\frac{\partial p}{\partial \eta}\right)\nabla_\eta \phi = \mathbf{F}$$

$$\frac{dw}{dt} + g\left(1 - \frac{1}{m}\frac{\partial p}{\partial \eta}\right) = F_z$$

$$\frac{dT}{dt} - \frac{RT}{pC_p}\frac{dp}{dt} = \frac{Q}{C_p}$$

$$\frac{1}{p}\frac{dp}{dt} + \frac{C_p}{C_v}D_3 = \frac{Q}{C_v T}$$

$$\frac{d\phi}{dt} - wg = 0$$

$$\frac{dm}{dt} + mD + \frac{\partial \dot{\eta}}{\partial \eta} = 0$$

VFE discretization (cont)

$$\frac{\partial \phi}{\partial \eta} = -m \frac{RT}{p} \Rightarrow T = -\frac{p}{mR}\frac{\partial \phi}{\partial \eta}$$

$$m \equiv \frac{\partial \pi}{\partial \eta}$$

$$D_3 \equiv \nabla_\eta \cdot \mathbf{V} + \frac{1}{m}\frac{p}{RT}\nabla_\eta \phi \cdot \left(\frac{\partial \mathbf{V}}{\partial \eta}\right) - \frac{g}{m}\frac{p}{RT}\frac{\partial w}{\partial \eta}$$

VFE discretization (cont)

Semi-implicit semi-Lagrangian system

$$D^+ + \frac{\Delta t}{2}\nabla^2\phi^+ + \frac{RT^*}{\pi^*}\frac{\Delta t}{2}\nabla^2 p^+ = R_D$$

$$w^+ + \frac{\Delta t}{2}\frac{g}{m^*}m^+ - \frac{\Delta t}{2}\frac{g}{m^*}\frac{\partial}{\partial\eta}p^+ = R_w$$

$$p^+ + \frac{C_p}{C_v}\frac{\Delta t}{2}\pi^* D^+ - g\frac{C_p}{C_v}\frac{\Delta t}{2}\frac{\left(\pi^*\right)^2}{RT^* m^*}\frac{\partial w^+}{\partial\eta} = R_p$$

$$\phi^+ - g\frac{\Delta t}{2}w^+ = R_\phi$$

$$m^+ + \frac{\Delta t}{2}m^* D^+ = R_m$$

VFE discretization (cont)

Elimination of variables, applying derivatives by parts leads to the structure equation:

$$\left\{-\frac{1}{c_s^{\,2}}+\left(\frac{\Delta t}{2}\right)^2\left[\nabla^2+\frac{1}{H^2}\left(\frac{\pi^*}{m^*}\frac{\partial}{\partial\eta}\left\{\frac{\pi^*}{m^*}\frac{\partial}{\partial\eta}\right\}+\frac{\pi^*}{m^*}\frac{\partial}{\partial\eta}\right)\right]+\left(\frac{\Delta t}{2}\right)^4 N^2\nabla^2\right\}w^+=R_c$$

where

$$c_s^{\,2}\equiv\frac{C_p}{C_v}RT^*;\quad H\equiv\frac{RT^*}{g};\quad N^2\equiv\frac{g^2}{C_pT^*}$$

Variable linearized map factor

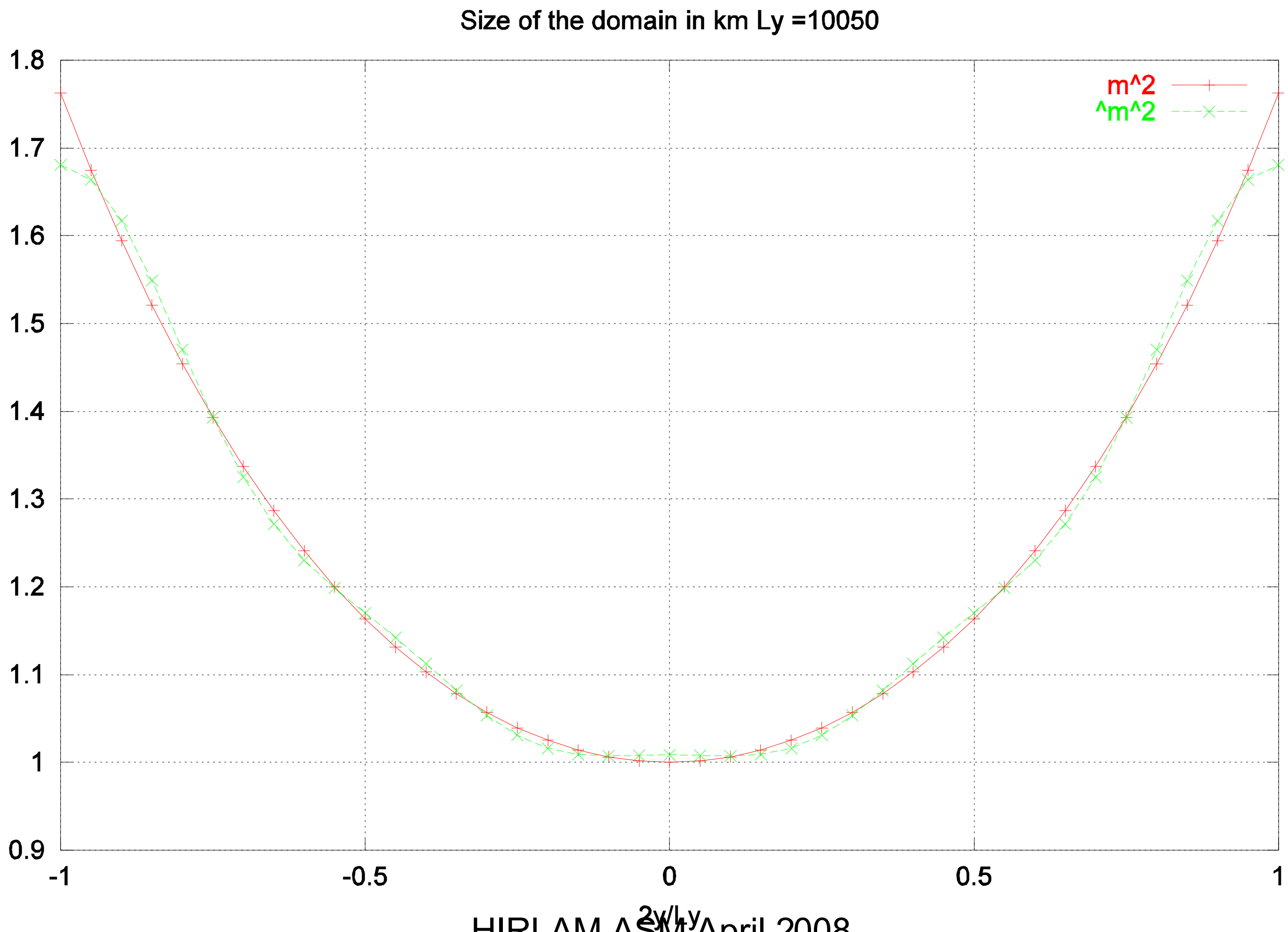
- Simmons & Temperton (1997): Stability of the two-time-level semi-implicit semi-Lagrangian scheme
- Yessad & Bénard (1996): LSIDG option
- Voitus (2004): Application to ALADIN
- Preliminary consideration of Simmons & Temperton method on Voitus equations: linearized map factor should be close to real map factor for stability

Variable linearized map factor (cont)

- On a rotated Mercator projection, the map factor can be closely approximated in bi-Fourier space by only a few components
- The solution of the Helmholtz equation involves a banded matrix with few diagonals

Variable linearized map factor (cont)

Approximation of m^2 with three Fourier components (4 coefficients)



Frequent update of the LBC

- Within the philosophy “overspecify and relax”
- Update every time-step of the host model
- Use weak coupling in the lowest layers
- Tune the relaxation coefficients
- Use an interpolation producing well-balanced fields

Transparent lateral boundary conditions

- Following the ideas of Engquist & Majda
- In close collaboration with ALADIN
- It works very well for linear GP models
  - About to be finished with vertical shear
  - Later, full non-linear implementation
- Needs adapting to spectral models
  - Extrinsic LBC
  - Iterative LBC

Dynamics-physics interface

- New staff member at DMI
- Allow physics and dynamics to be run at different resolutions
- Second-order in time coupling (SLAVEPP)

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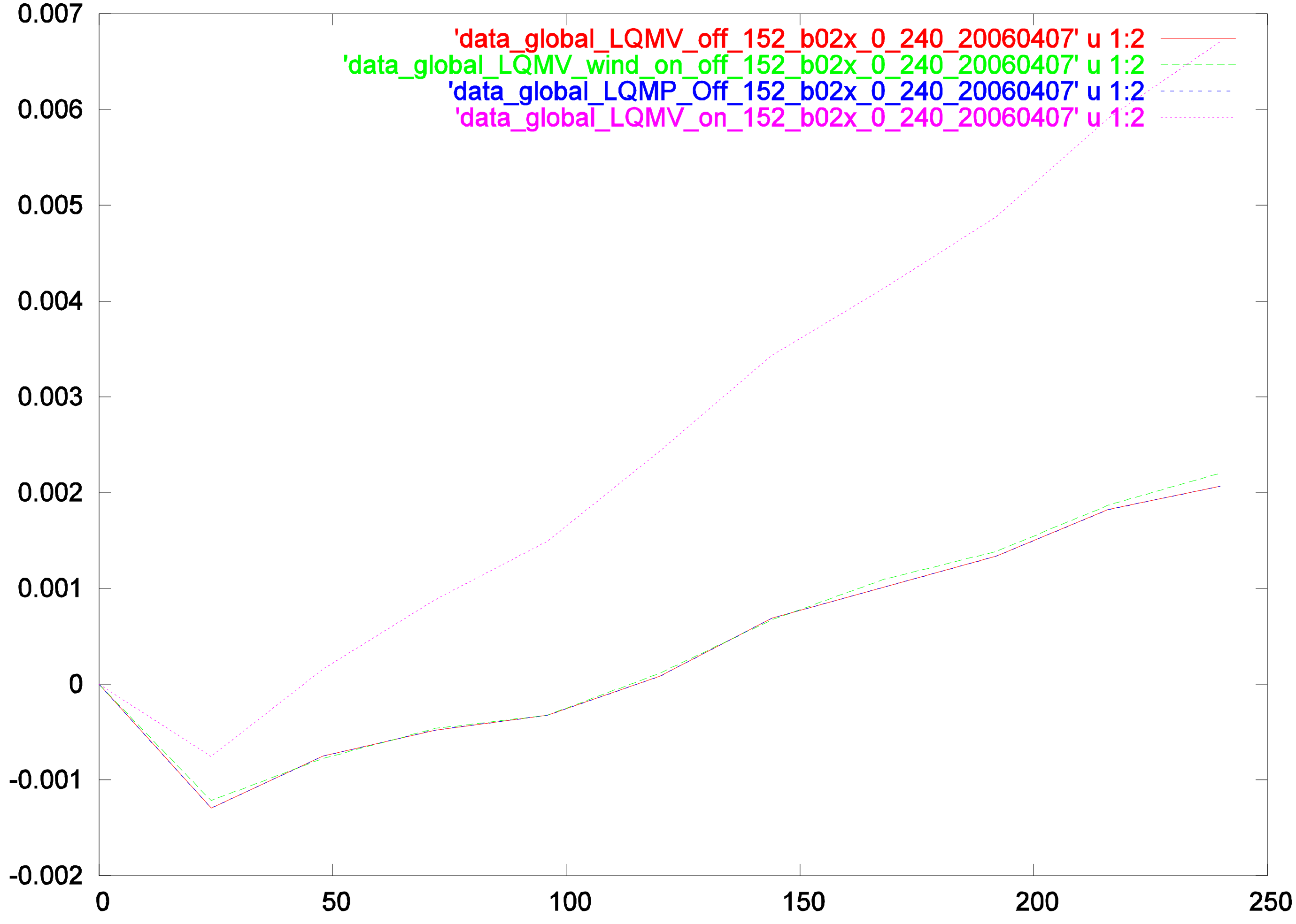
Conservative semi-Lagrangian advection

- Quasi-monotone interpolation is needed in the wind but is also done on ln p_s
- Eliminating quasi-monotonicity in the continuity equation improves conservation of mass
- New scheme proposed by Kaas (2008) will be tested when ready
- More accurate interpolation in the tracer fraction improves conservation but introduces noise



0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
-0.001
-0.002
0
50
100
150
200
250
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Semi-elastic model as an alternative

- In the semi-elastic model the acoustic waves are filtered out
- This can in principle improve the stability properties
- So far, this expectation has not been fulfilled