Status and plans of HIRLAM's dynamics

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Outline

- Vertical Finite-element discretization
- Non-constant linearized map factor
- Frequency of LBC update
- Physics-dynamics interface
  - Influence of dynamics settings
  - Computations in different grids
  - Second-order accurate interface
- Conservation in semi-Lagrangian
- Plans

Vertical Finite Element discretization

$$\frac{d\mathbf{V}}{dt} + R\nabla T + RT\nabla q - \frac{RT}{\tilde{\partial}\phi}\left(\tilde{\partial}+1\right)\nabla\phi + RT\,\frac{\left[\tilde{\partial}^2\right]\phi}{\left(\tilde{\partial}\phi\right)^2}\nabla\phi - R\frac{\tilde{\partial}T}{\tilde{\partial}\phi}\nabla\phi = \mathbf{F}_{\mathbf{V}}$$

$$\frac{dW}{dt} + \gamma\frac{d}{dt}\left(\frac{1}{g}\mathbf{V}\cdot\nabla\phi\right) + g\left(1 + \frac{R}{\tilde{\partial}\phi}\left(\tilde{\partial}+1\right)T - RT\,\frac{\left[\tilde{\partial}^2\right]\phi}{\left(\tilde{\partial}\phi\right)^2}\right) = F_W$$

$$\frac{dT}{dt} + \frac{RT}{C_v}\left(\nabla\cdot\mathbf{V} + g\,\frac{\tilde{\partial}W}{\tilde{\partial}\phi} - (1-\gamma)\nabla\phi\cdot\frac{\tilde{\partial}\mathbf{V}}{\tilde{\partial}\phi} + \gamma\mathbf{V}\cdot\frac{\nabla\tilde{\partial}\phi}{\tilde{\partial}\phi}\right) = F_T$$

$$\frac{d\phi}{dt} - gW - \gamma\mathbf{V}\cdot\nabla\phi = 0$$

$$\frac{\partial q}{\partial t} + \tilde{\mathrm{N}}\left(\nabla\cdot\mathbf{V}\right) + \nabla q\cdot\tilde{\mathrm{N}}\left(\mathbf{V}\right) = 0$$

VFE discretization (cont)

Here

$$\pi : hydrostatic\ \ pressure$$

$$q \equiv \ln \pi_s$$

$$\phi : geopotential$$

$$W \equiv w - \frac{\gamma}{g} \mathbf{V} \cdot \nabla \phi \qquad \gamma : switch$$

$$\tilde{\partial} F(\sigma) \equiv \sigma \frac{\partial F}{\partial \sigma}$$

$$\tilde{\mathrm{N}} F \equiv \int_0^1 F(\sigma) d\sigma$$

VFE discretization (cont)

Structure equation:

$$\left[1-(\Delta t)^2 c_*^2\left(\Delta+\frac{1}{H_*^2}\tilde{\mathrm{P}}\left(\tilde{\partial}+1\right)\tilde{\partial}\right)-(\Delta t)^4 N_*^2 c_*^2 \Delta\tilde{\mathrm{P}}\right]W_A^+ = R_C$$

where

$$\tilde{\mathrm{P}} \equiv diagonal\ \left(1,1,\ldots\ldots,1,0\right)$$

Is a projection operator

$$c_*^2 \equiv \frac{C_p}{C_v} RT^*$$

$$H_* \equiv \frac{RT^*}{g}$$

$$N_*^2 \equiv \frac{g^2}{C_p T^*}$$

With the constraint:

$$\left(\tilde{\partial}+1\right)\tilde{S} = 1$$

$$\tilde{S}F(\sigma) \equiv \frac{1}{\sigma}\int_0^\sigma F(x)dx$$

VFE discretization (cont)

The structure equation can be factorized following the ALADIN procedure giving:

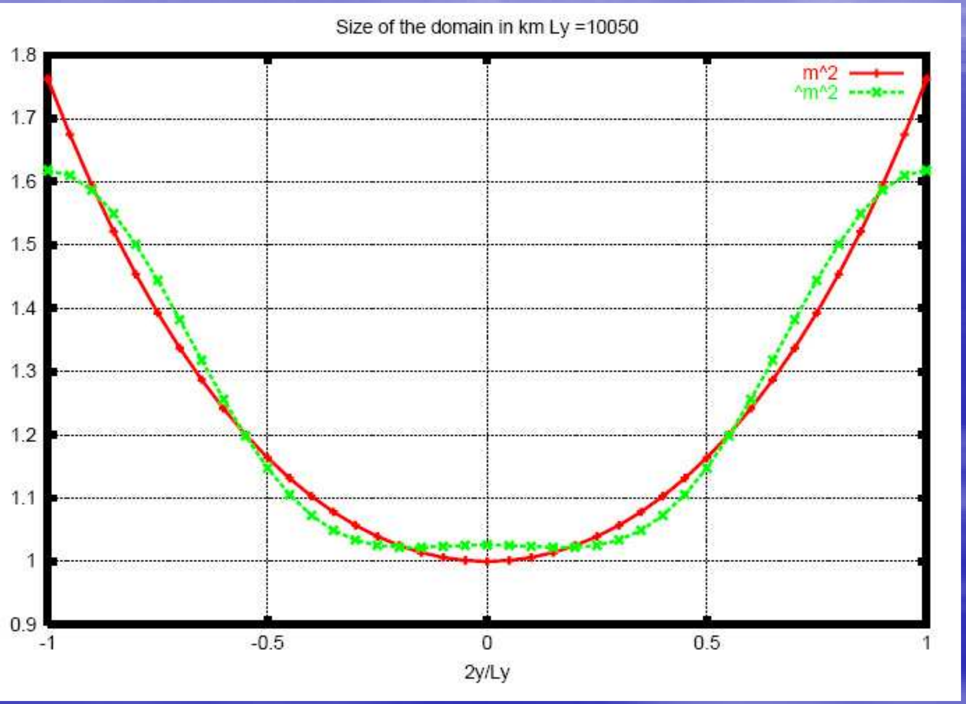
$$\left[1-(\Delta t)^2 \Delta \tilde{\mathrm{B}}\right] W_A^{+} = \hat{R}_c^{'}$$

where

$$\tilde{\mathrm{B}} \equiv \left(1-(\Delta t)^2 c_*^2 \frac{1}{H_*^2} \tilde{\mathrm{P}} \left(\tilde{\partial}+1\right) \tilde{\partial}\right)^{-1} \cdot \left(1+(\Delta t)^2 N_*^2 \tilde{\mathrm{P}}\right)$$

Hirlam – High Resolution Limited Area Model

Non-constant linearized map factor



Fourier estimation of the square map factor with three coefficients (a_0, a_1 and a_2) in comparisson to the square map factor real value. L_y = 10.050km

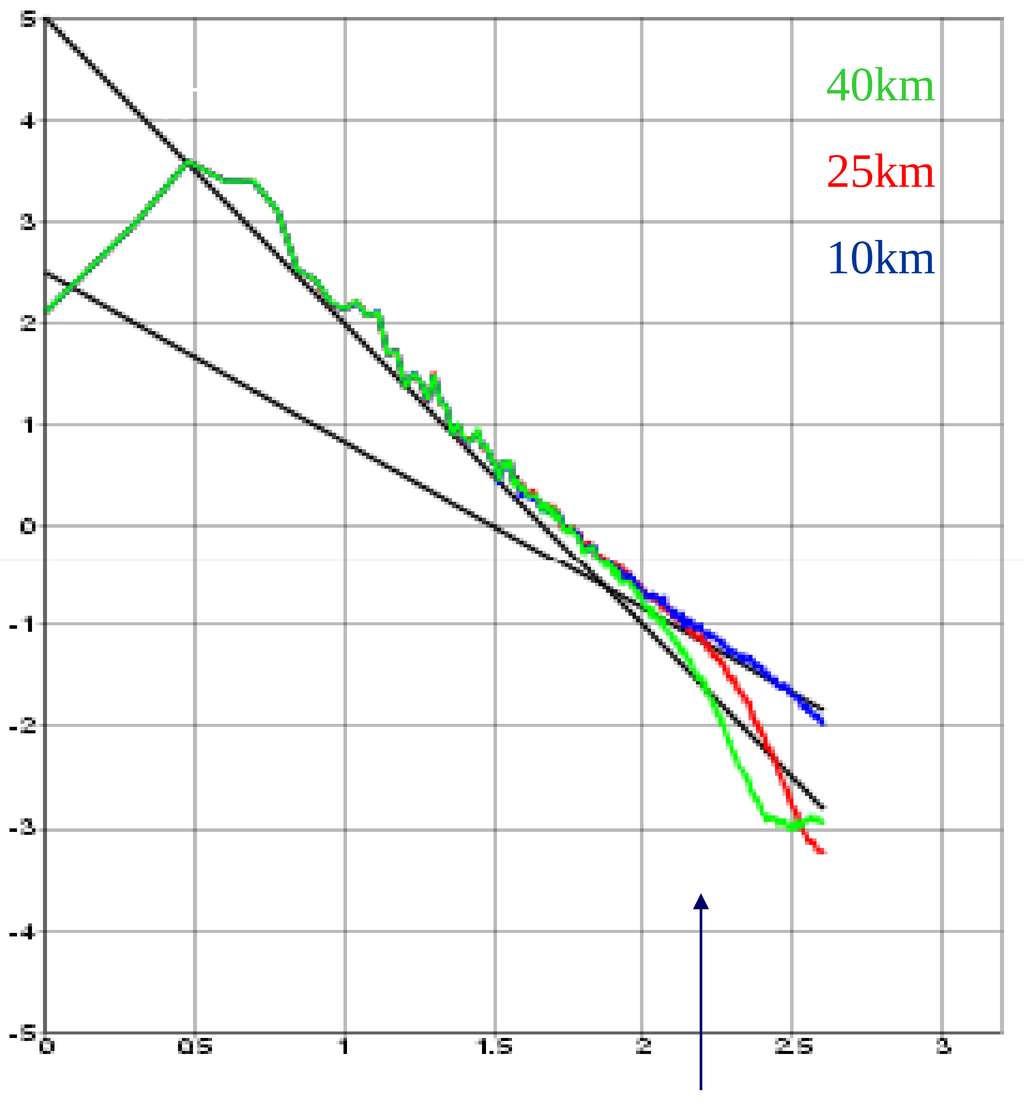
Frequency of LBC update

- Ultimate aim: Transparent LBC's (McDonald)
- In the meantime: Improve Davies's relaxation
- Simultaneous run of host and guest models
  - LBC updated up to the time-step of host
- Plans
  - (SS)DFI of LBC
  - MCUF (Monitoring of the Coupling Update Frequency)
  - Further adaptation to the guest model conditions

Physics-dynamics interface

- Influence of the dynamics settings (Sander’s talk)
  – Horizontal diffusion (spectral)
  – Semi-Lagrangian interpolations (SLHD, QM, …)
- Physics and dynamics computed on different grids
- Plan
  – Second-order accurate treatment of the physics tendencies

Spectra of total KE



Mass conservation in s-L

$$(\ln p_s)^+ = \int_0^1 \frac{\partial B}{\partial \eta} \left\{ (\ln p_s)^0 + \Delta t \left(\frac{\partial (\ln p_s)}{\partial t} + \mathbf{V}(\eta) \cdot \nabla \ln p_s \right)^{1/2} \right\} d\eta$$

First term interpolated with 2D quasi-monotone cubic Lagrange polynomial
Second term interpolated with 3D linear interpolation

“New form of continuity equation” (ECMWF)

Original idea by Ritchie & Tanguay (1995):
Implemented at ECMWF by C. Temperton (1995)

$$Add\ and\ substract\ \frac{d}{dt}\frac{\Phi_s}{R_d\overline{\overline{T}}}\ in\ the\ continuity\ equation$$

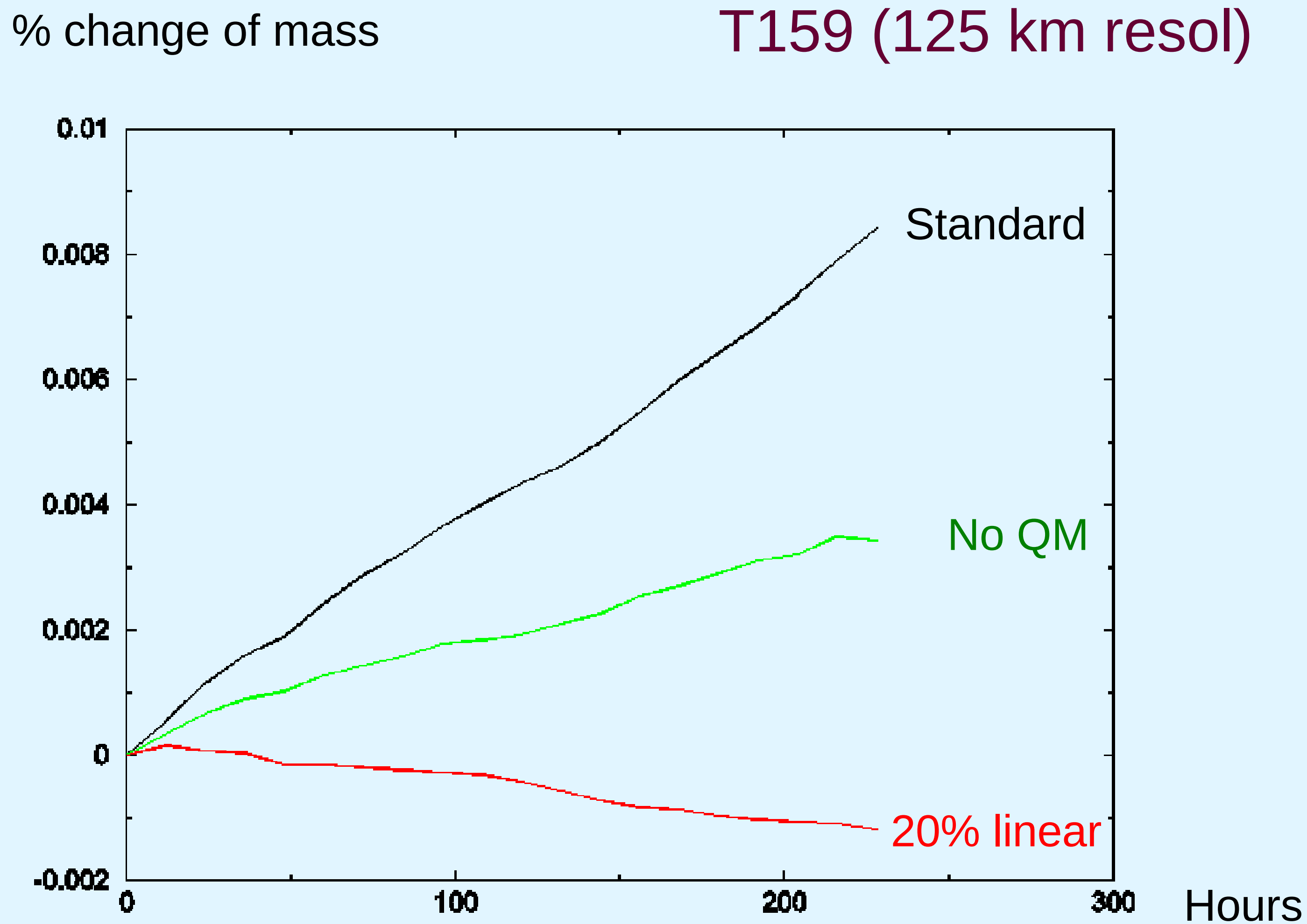
Then the cubically interpolated quantity is

$$\left(\ln p_s + \frac{\Phi_s}{R_d\overline{\overline{T}}}\right)\ which\ is\ much\ smoother\ than\ \ln p_s$$

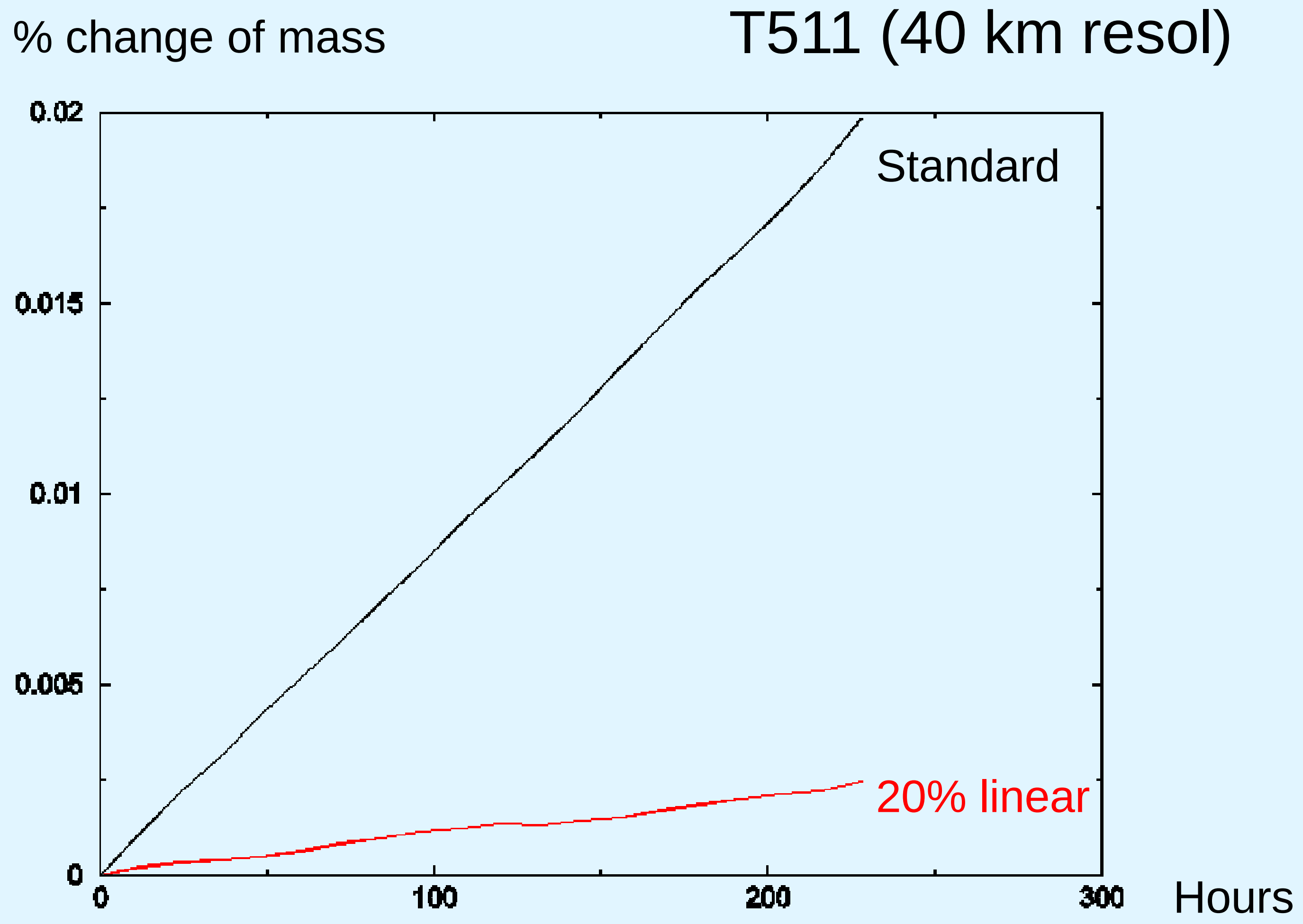
Change of interpolator in the continuity eq.

Apply a combination of linear and cubic interpolations instead of quasi-monotone cubic interpolation
(leaving the same the term tri-linearly interpolated)

T159 (125 km resol)



T511 (40 km resol)



Plans

- Continue development of VFE
- Test the developed options (physics at different resolution, non-constant linearized map-factor, conservation, increased LBC frequency)
- Eliminate the extension zone from the grid-point computations
- Second order treatment of physics tendencies

Thank you