# Dynamics & Coupling

## *2005-2006 progress report*


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CHMI

# Diffusive chimney in NH dynamics

Work of: M. Vörös (Hu), R. Brožková (Cz) and F. Váňa (Cz)

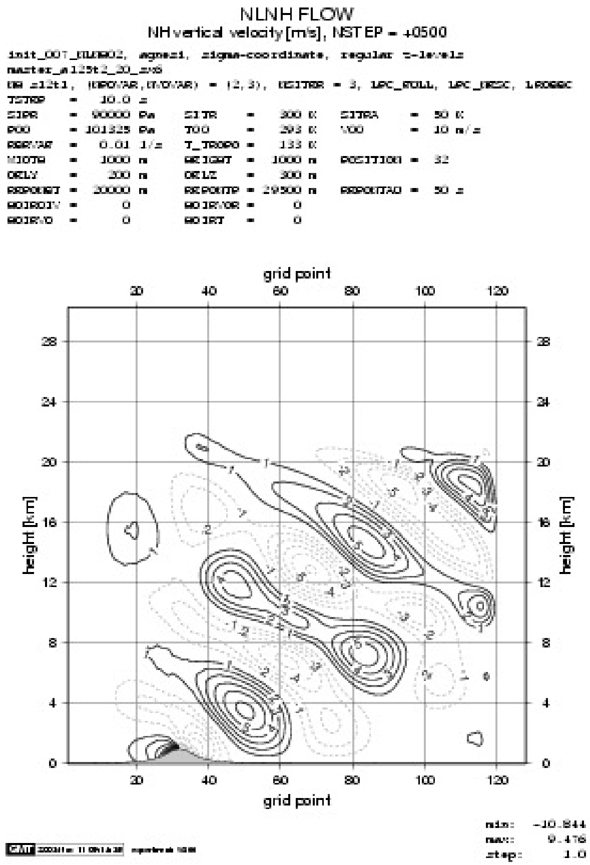


Fig. 7: NH sl2tl, $d_3$ + new BBC, no diffusion.

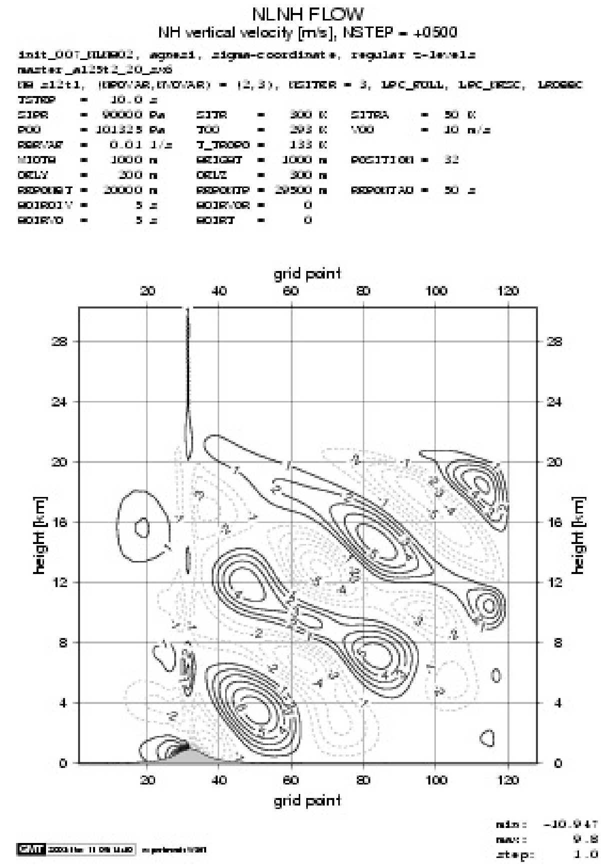


Fig. 8: NH sl2tl, $d_3$ + new BBC, diffusion.

# Diffusive chimney in NH dynamics

BBC for the term $\frac{\partial \tilde{p}}{\partial \pi}$

$$\left(\frac{\partial \tilde{p}}{\partial \pi}\right)_S = \frac{\left[-\frac{RT}{p}\nabla p - \nabla \phi + \mathcal{V}\right]_S \cdot \nabla \phi_S + J_S - g\,\mathcal{W}_S}{g^2 + \left(\nabla \phi_S\right)^2}$$

$$J_S = \frac{\partial^2 \phi_S}{\partial x^2} u_S^2 + 2\frac{\partial^2 \phi_S}{\partial x \partial y} u_S v_S + \frac{\partial^2 \phi_S}{\partial y^2} v_S^2$$

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Here $\mathcal{V}$ and $\mathcal{W}$ are the source terms of momentum containing coriolis, diabatic tendencies and horizontal diffusion.

# Diffusive chimney in NH dynamics

Possible alternatives:

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Semi-Lagrangian Horizontal Diffusion = way to control damping properties of the SL interpolation according to the flow deformation.

$\Rightarrow$ SLHD solution for ALADIN NH dynamics?

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# Diffusive chimney in NH dynamics

ALADIN 2TL SISL:

$$X_F^+ = \left(1 - \frac{\Delta t}{2}\mathcal{L}\right)^{-1} \left[ \underbrace{\left(1 + \frac{\Delta t}{2}\mathcal{L}\right) X_O^- + \Delta t \mathcal{F}_O^- + \frac{\Delta t}{2}\mathcal{N}_O^*}_{SLHD} + \frac{\Delta t}{2}\mathcal{N}_F^* \right]$$

Extra spectral diffusion (= supporting diffusion) is needed for $u$, $v$ and $d$ (having $\phi_S$ in their $\mathcal{N}$).

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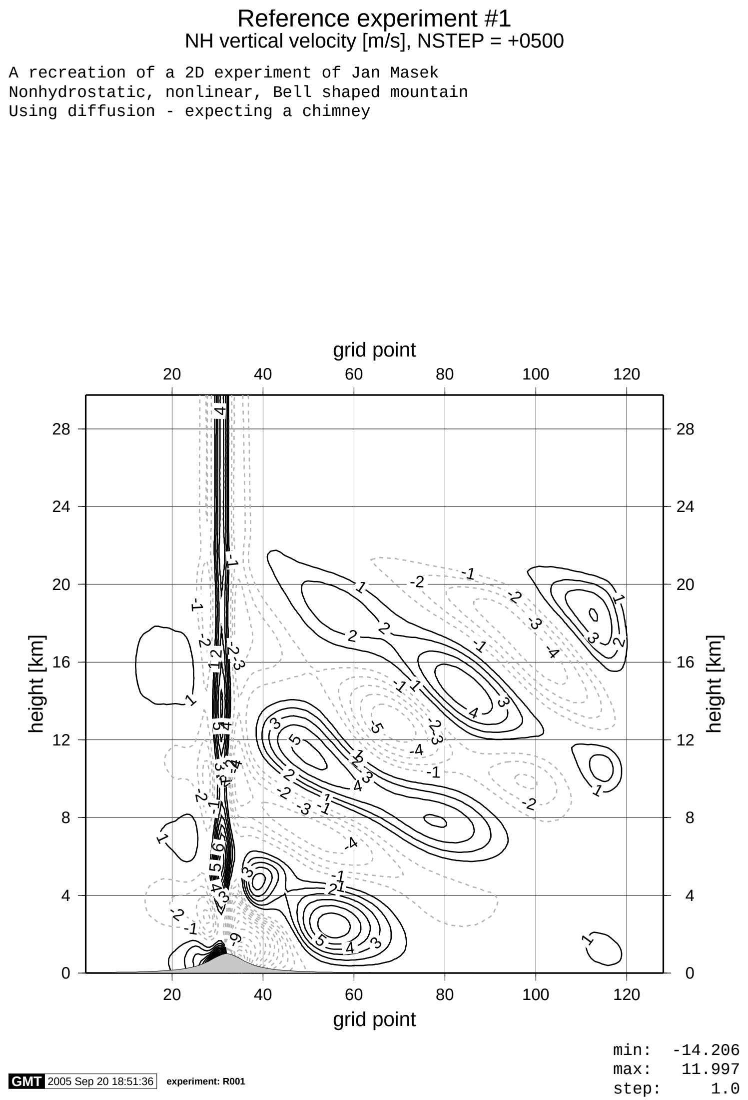


- Spectral diffusion

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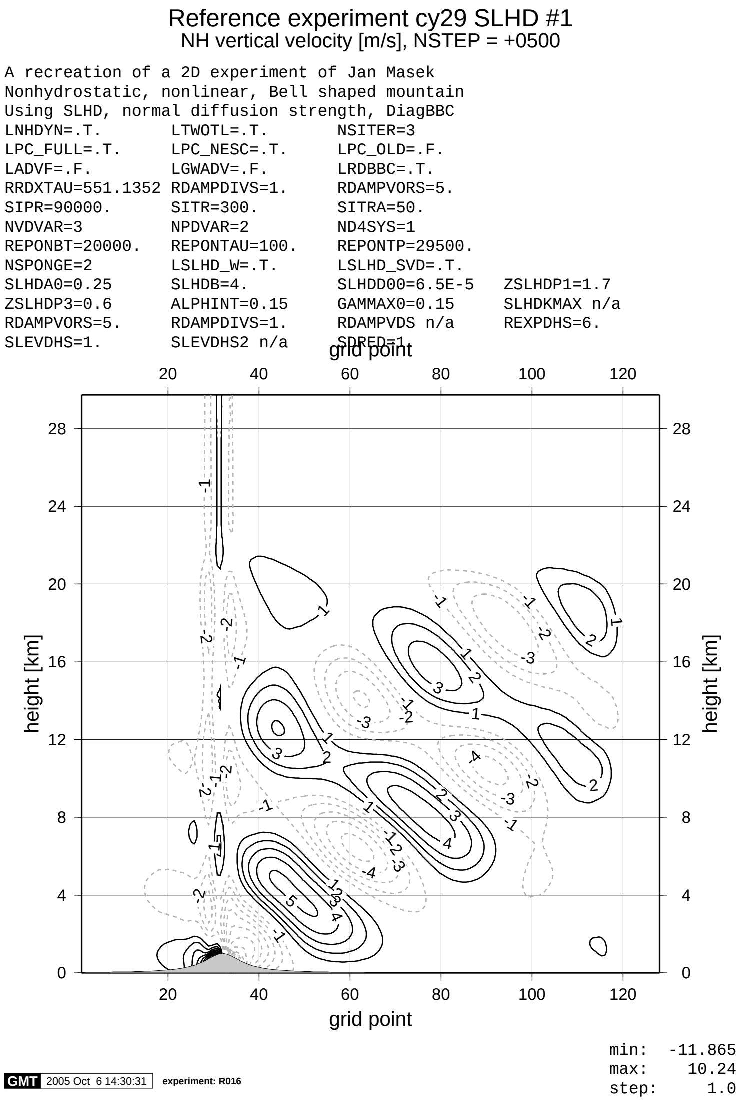


- Spectral diffusion
- Default SLHD

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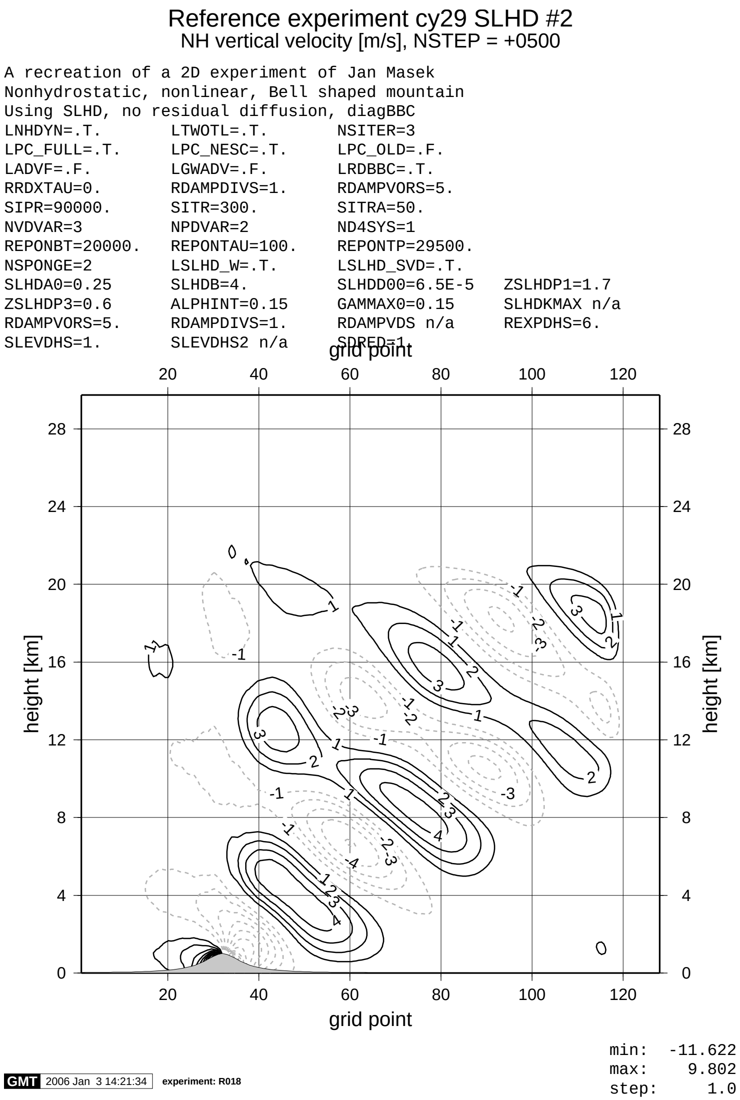


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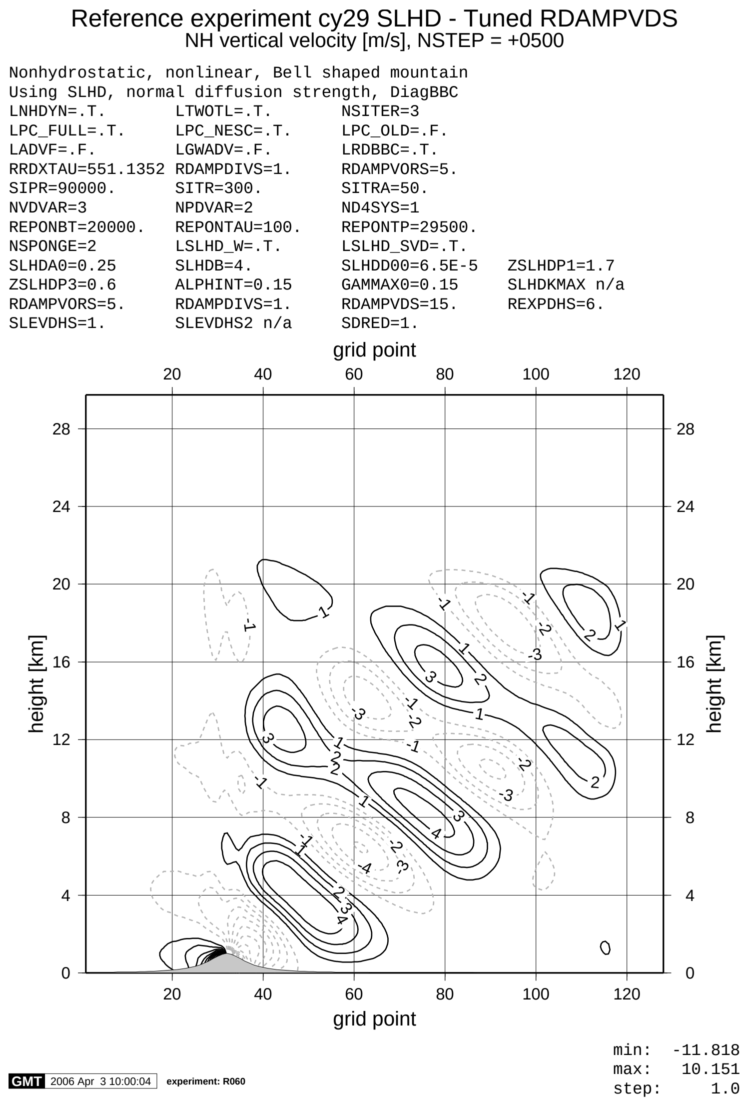
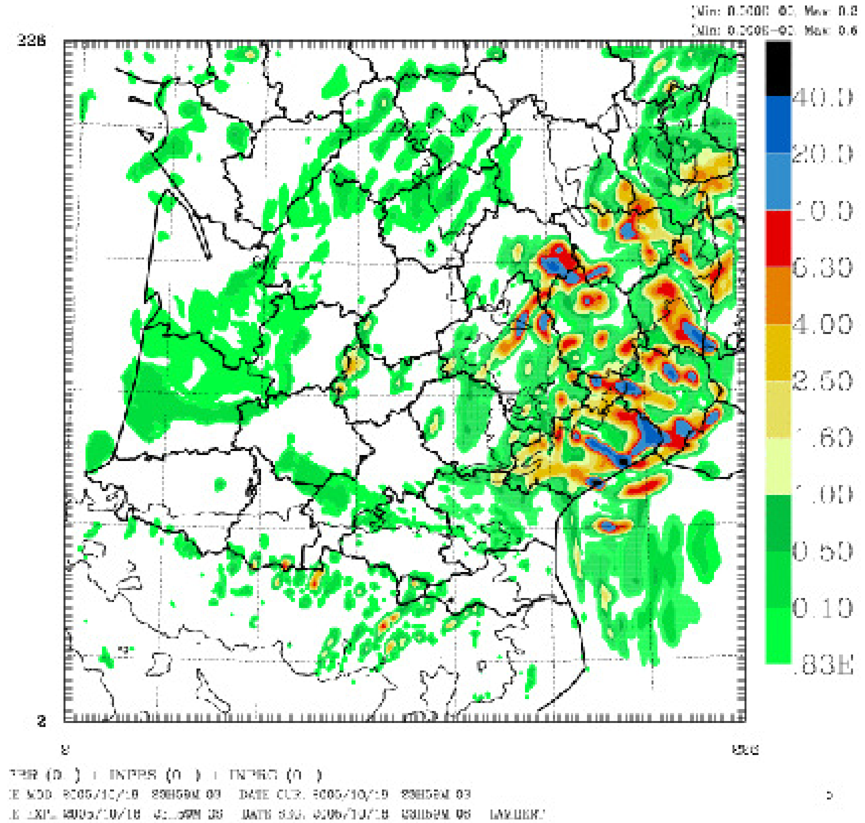


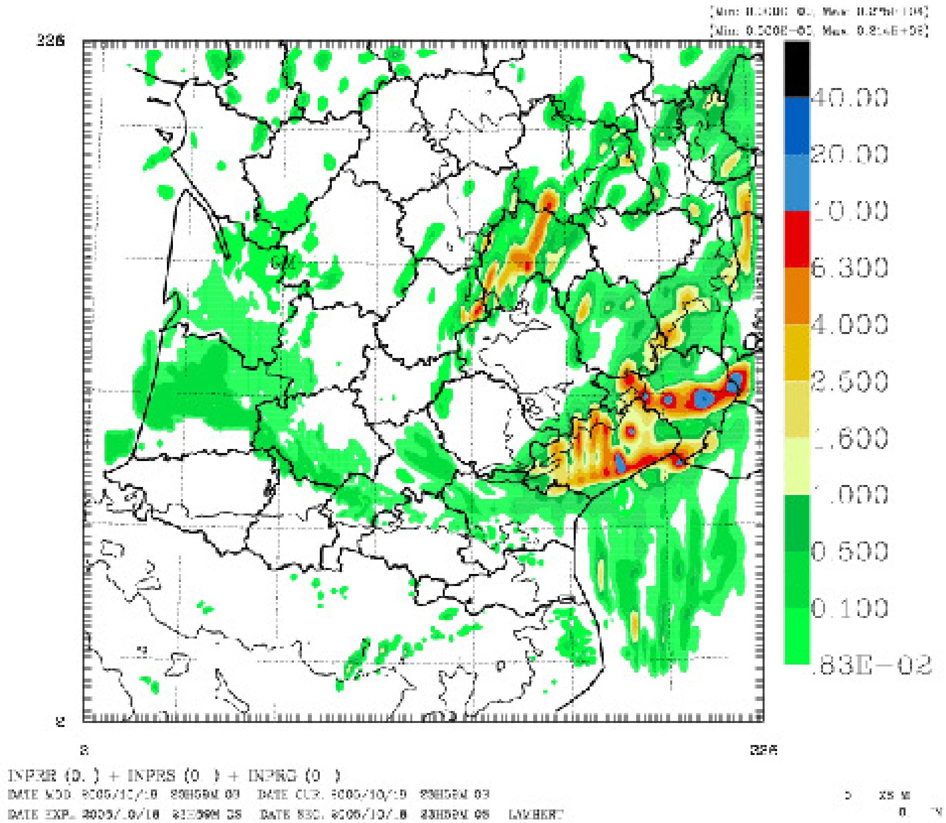

- Spectral diffusion
- Default SLHD
- Only GP part of SLHD
- New SLHD

# Diffusive chimney in NH dynamics

## AROME instantaneous rainfalls 19-Oct-2005 00 UTC




AROME MIDPYR old diffusion




AROME MIDPYR LRDBBC+SLHD

# Non-isothermal SI background

Work of: J. Vivoda (Sk)

$T^*, T_a^* \Rightarrow T^*(\eta), T_a^*(\eta)$

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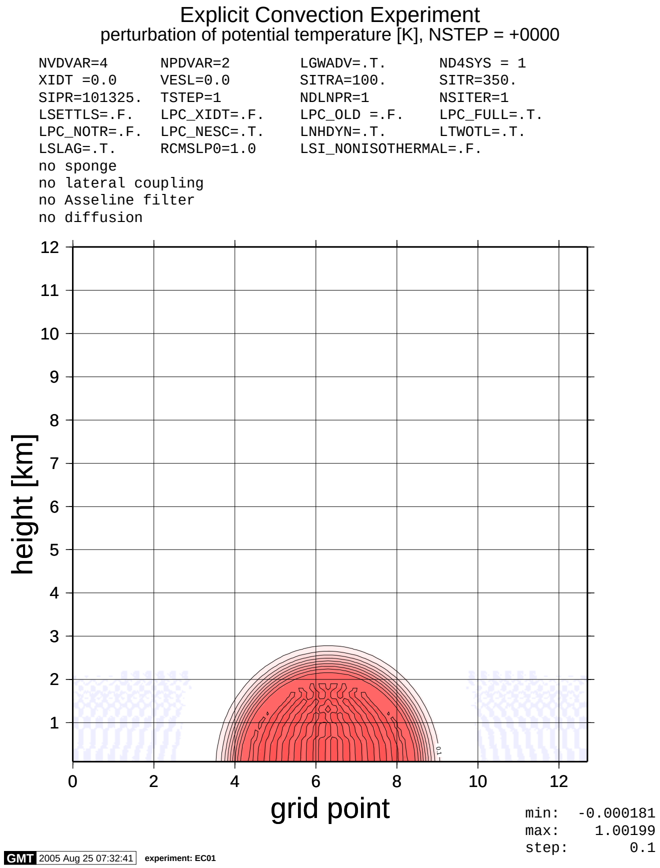
System becomes more complicated:

- Non trivial setup for $T^*(\eta)$, $T_a^*(\eta)$
- No analyze for optimal $T^*(\eta)$, $T_a^*(\eta)$ setting (at the moment)
- Helmholtz solver becomes the two equations system

# Non-isothermal SI background

## 2D explicit convection test




Initial state

# Non-isothermal SI background

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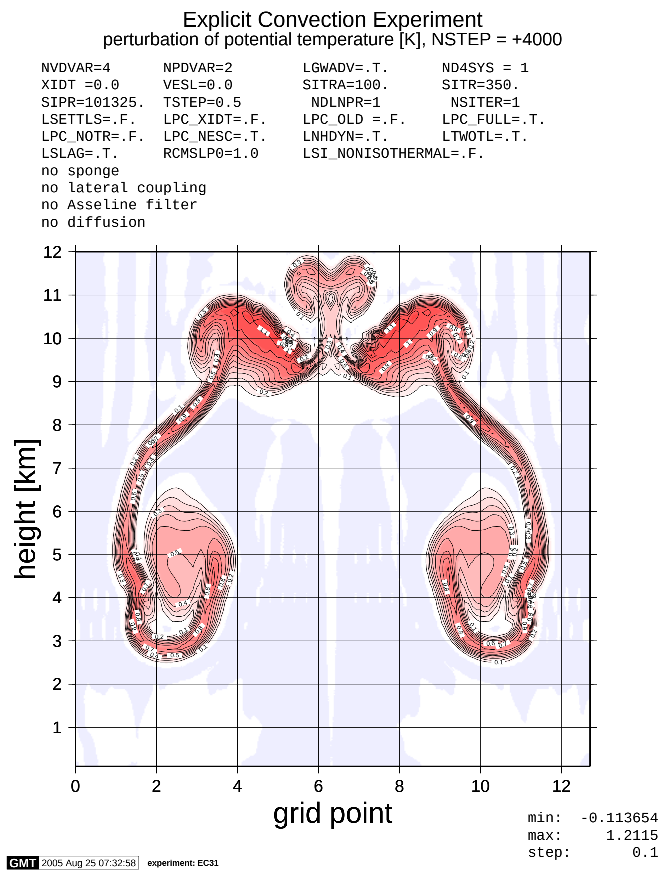


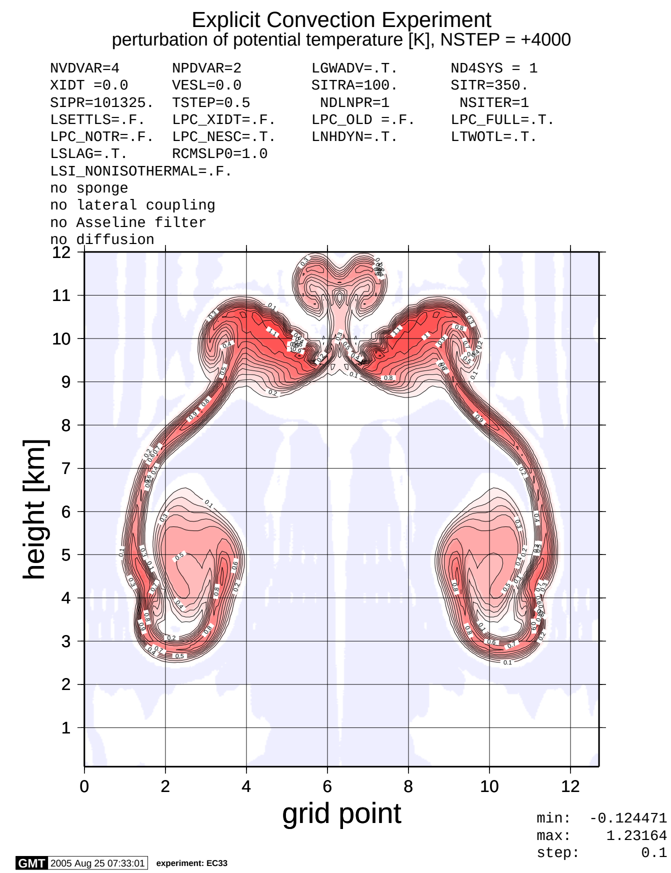


$\Delta t$ = 0.5 s ($\Delta x = \Delta z$ = 100 m)

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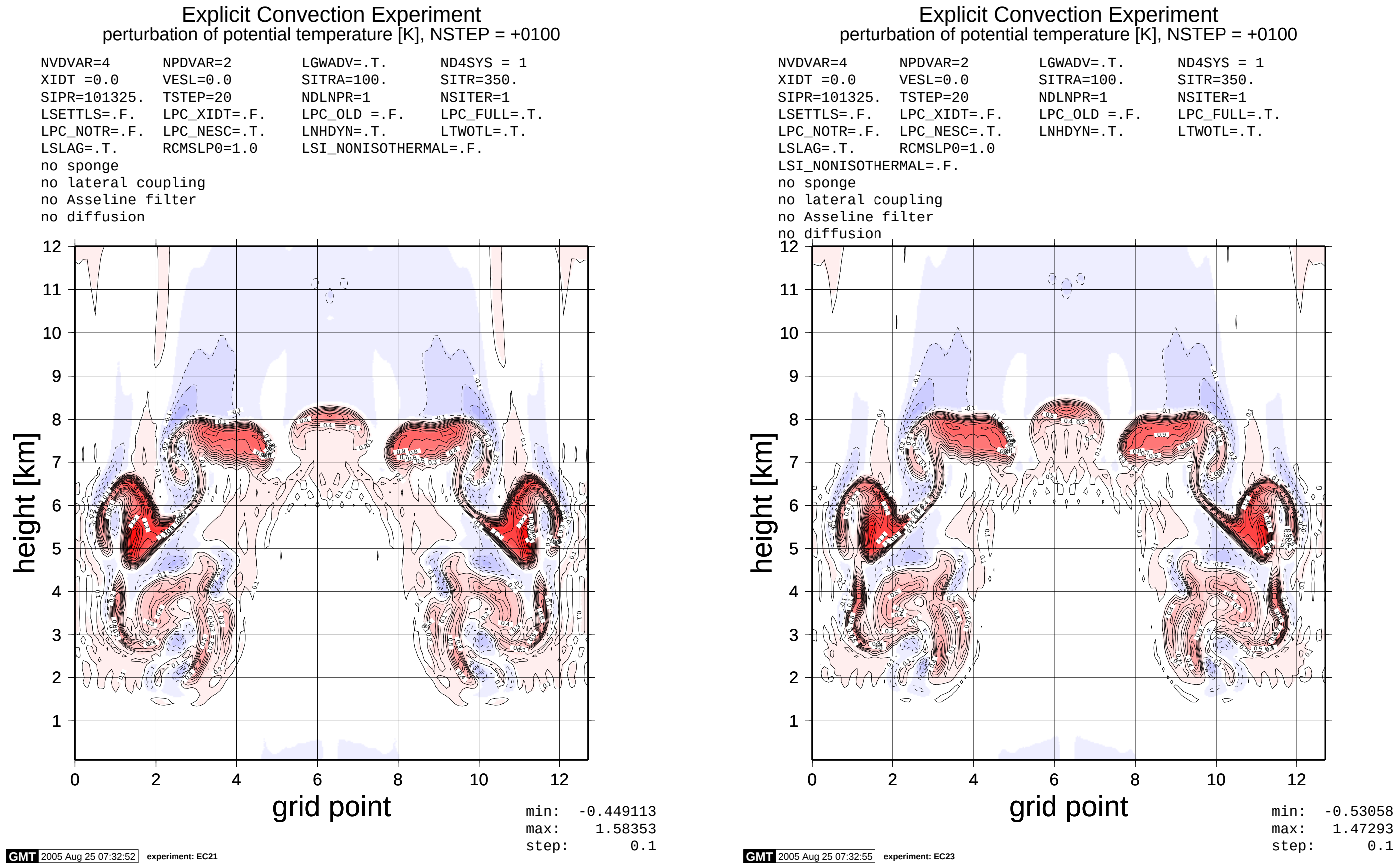


$\Delta t$ = 20. s ($\Delta x = \Delta z$ = 100 m)

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# Vertical Finite Element scheme

Work of: J. Vivoda (Sk)

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- First version of VFE implemented to the code $\rightarrow$ stable, efficient (2-3 % extra CPU) but (for the moment) noisy.
- Plan to code a hybrid FE/FD system with interchangeable parts.

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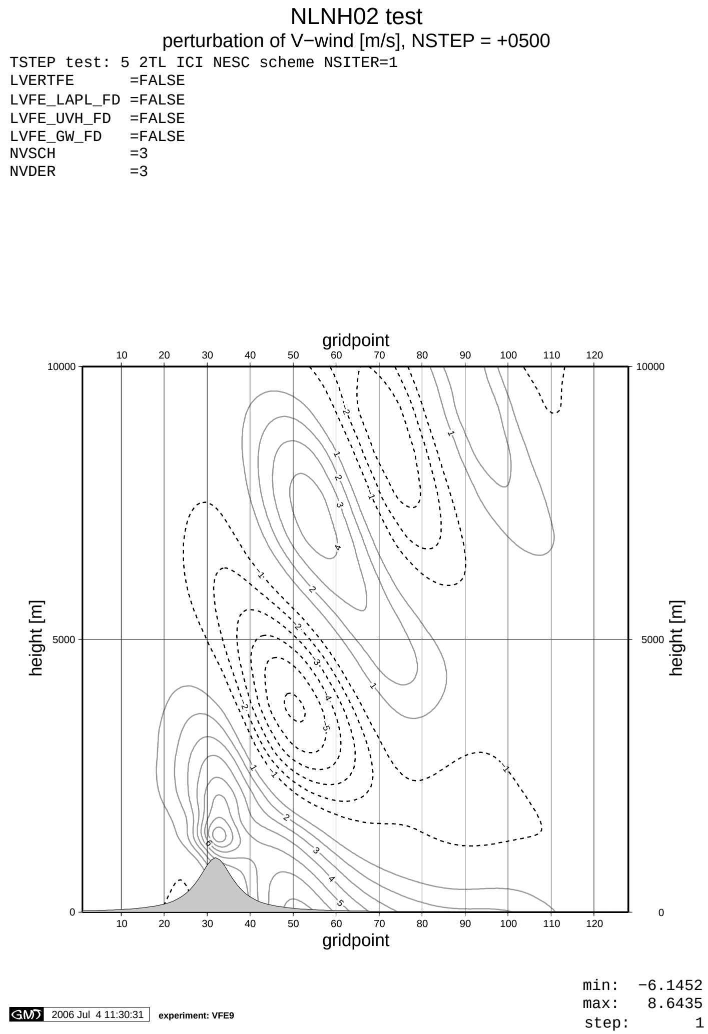


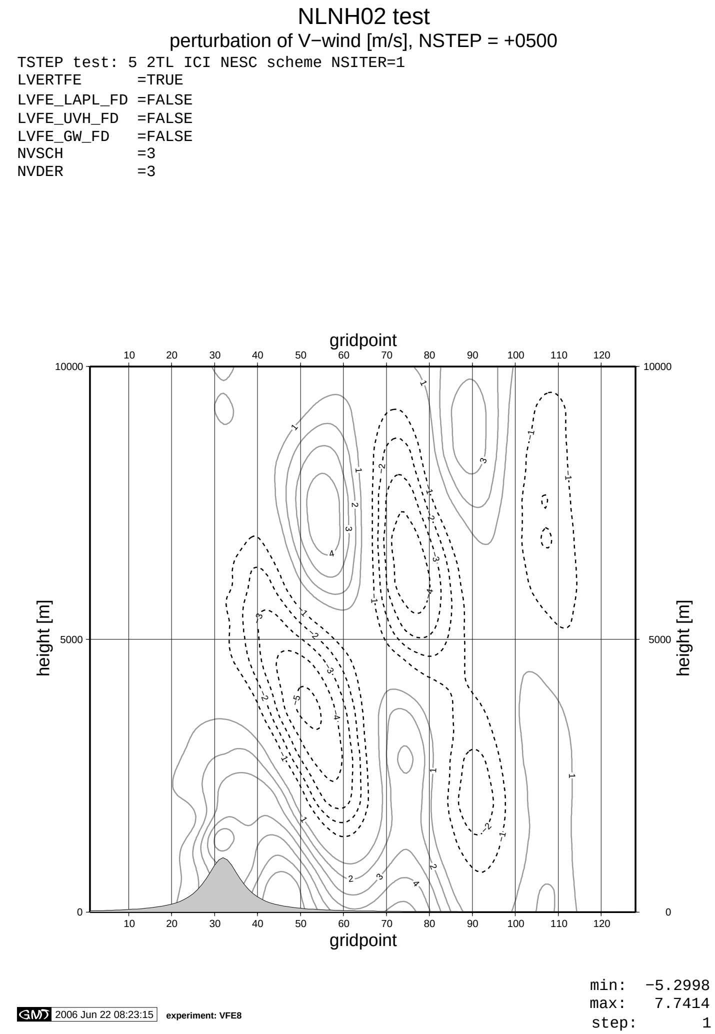


FD scheme versus full VFE

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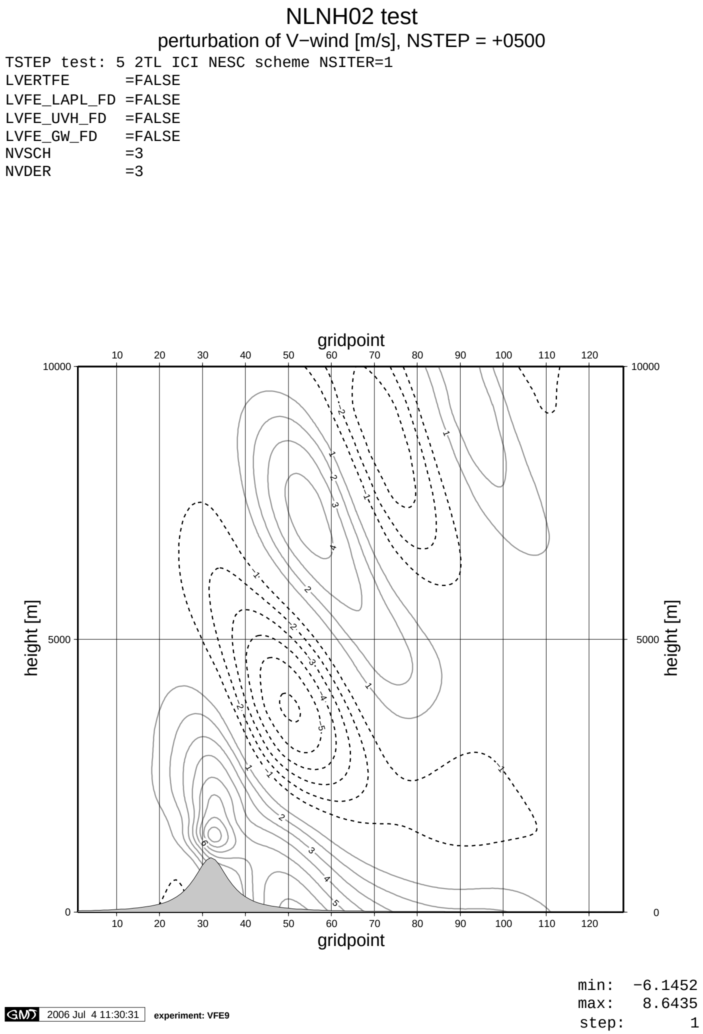
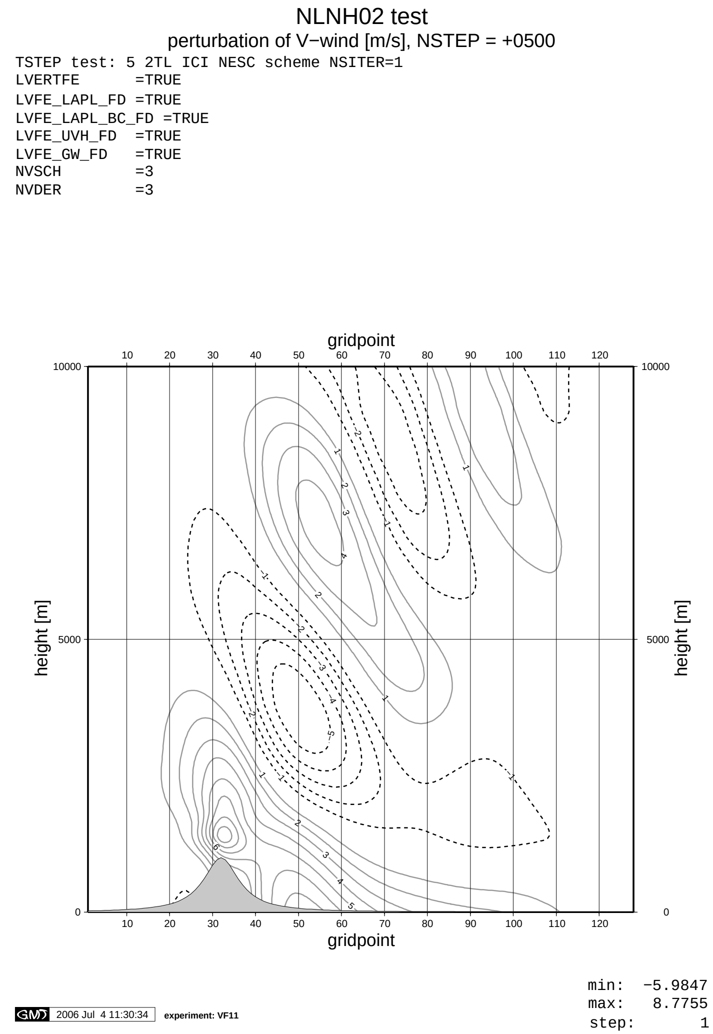
# Vertical Finite Element scheme




FD scheme versus FD with VFE integral operators

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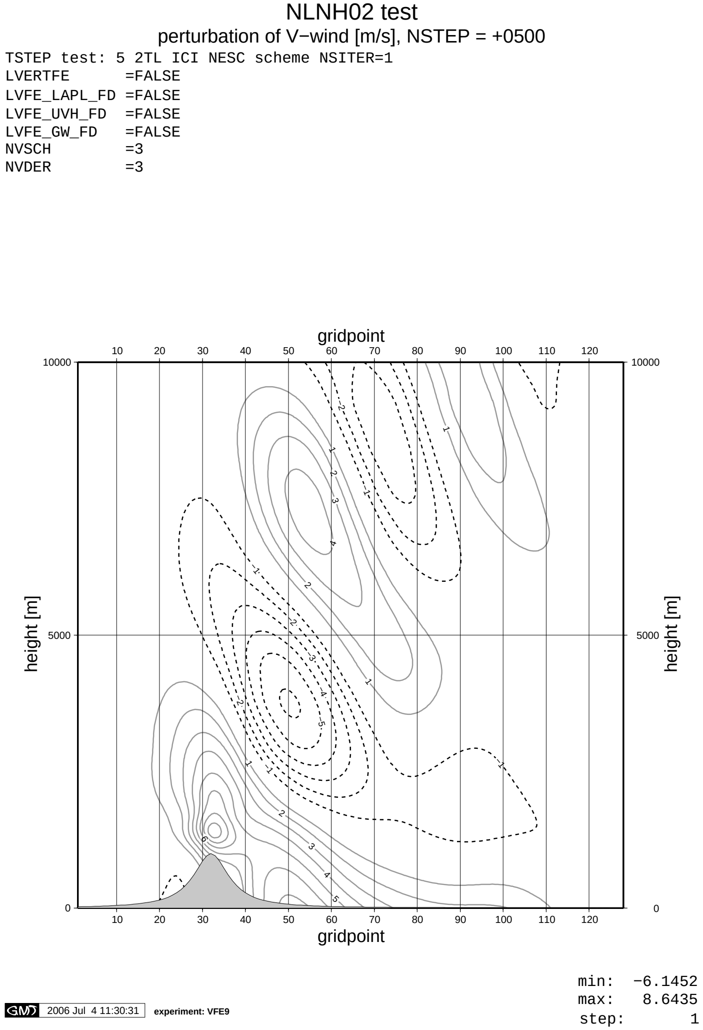
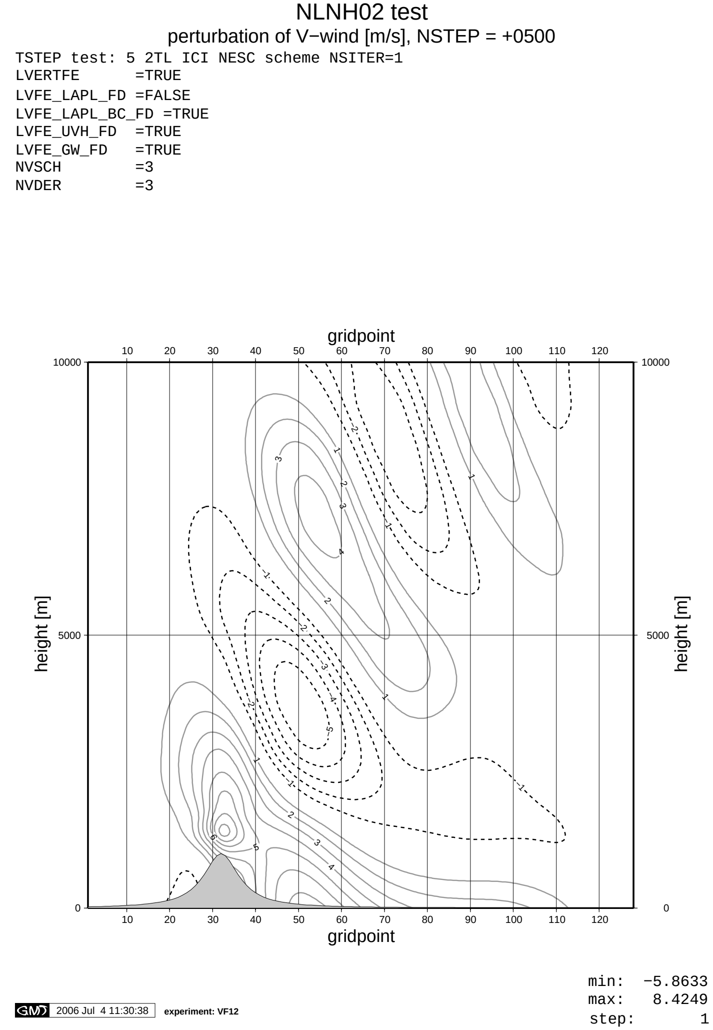
# Vertical Finite Element scheme




FD scheme vs. FD with VFE integ. and laplacian oper.

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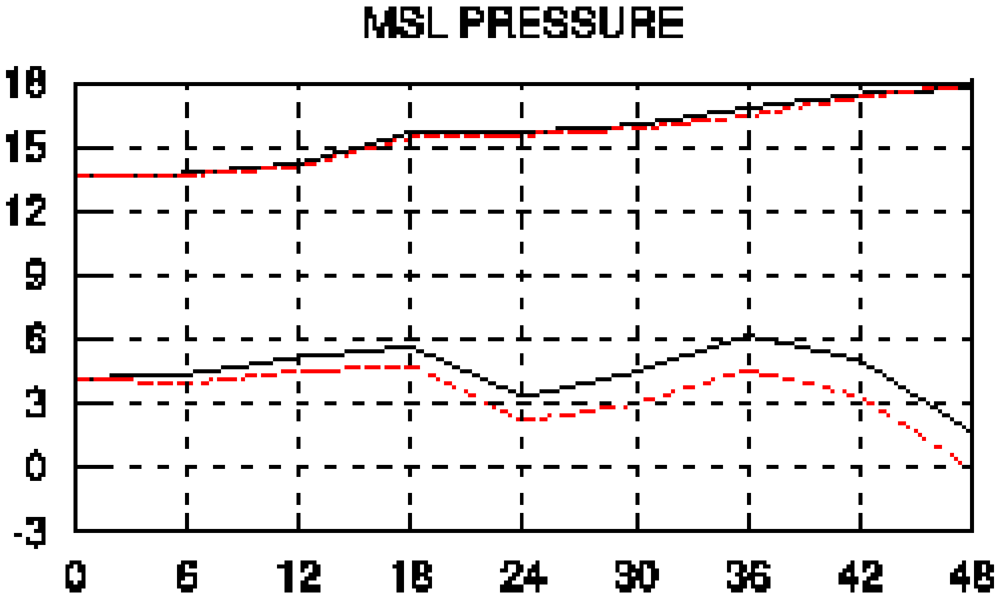
# New interpolators for SL

Work of: J. Mašek (Sk) and F. Váňa (Cz)

Motivation: SLHD affects conservative properties of the model ⇒ need to an improvement of the SL interpolators accuracy.




MSL pressure RMSE and BIAS for 15 days of parallel run

# New interpolators for SL

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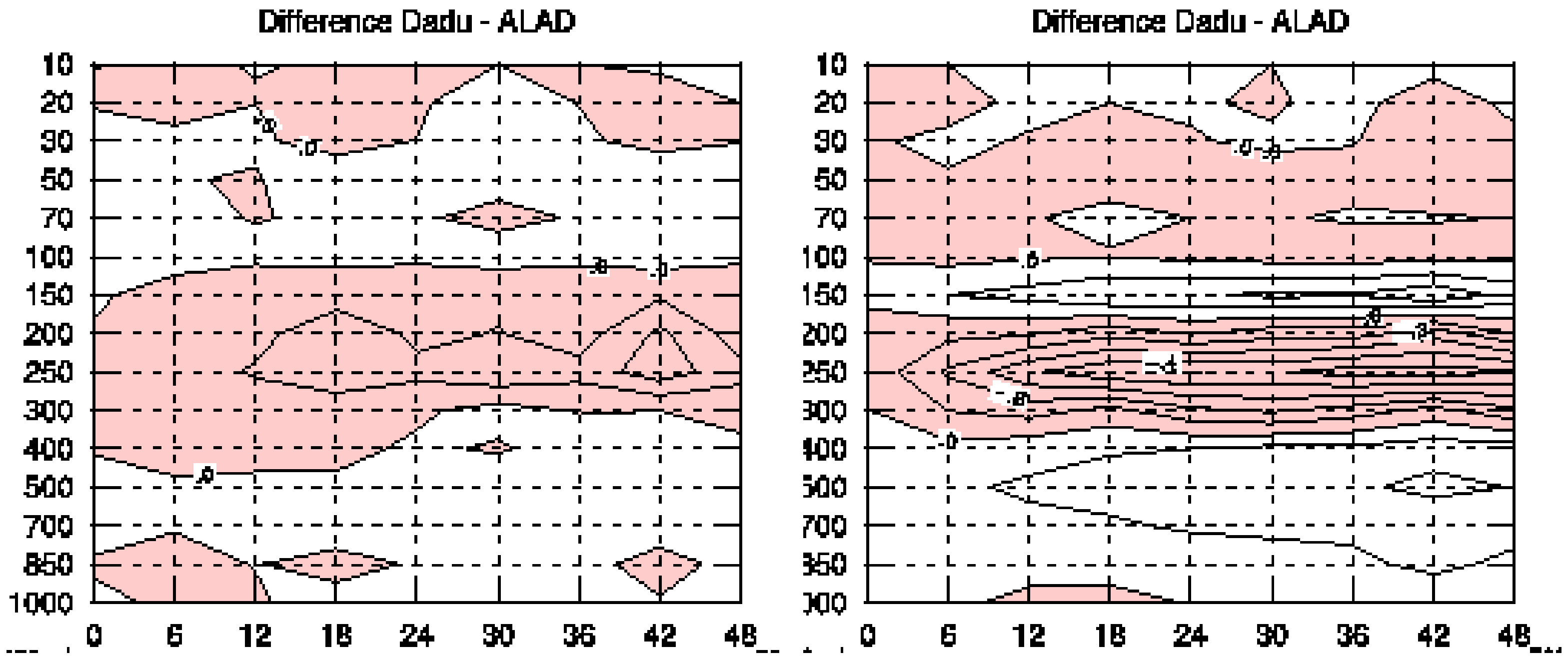
Motivation: Performance of the local splines is not superior to the Lagrangian cubic interpolation in SL.




temperature RMSE and BIAS for 15 days of parallel run

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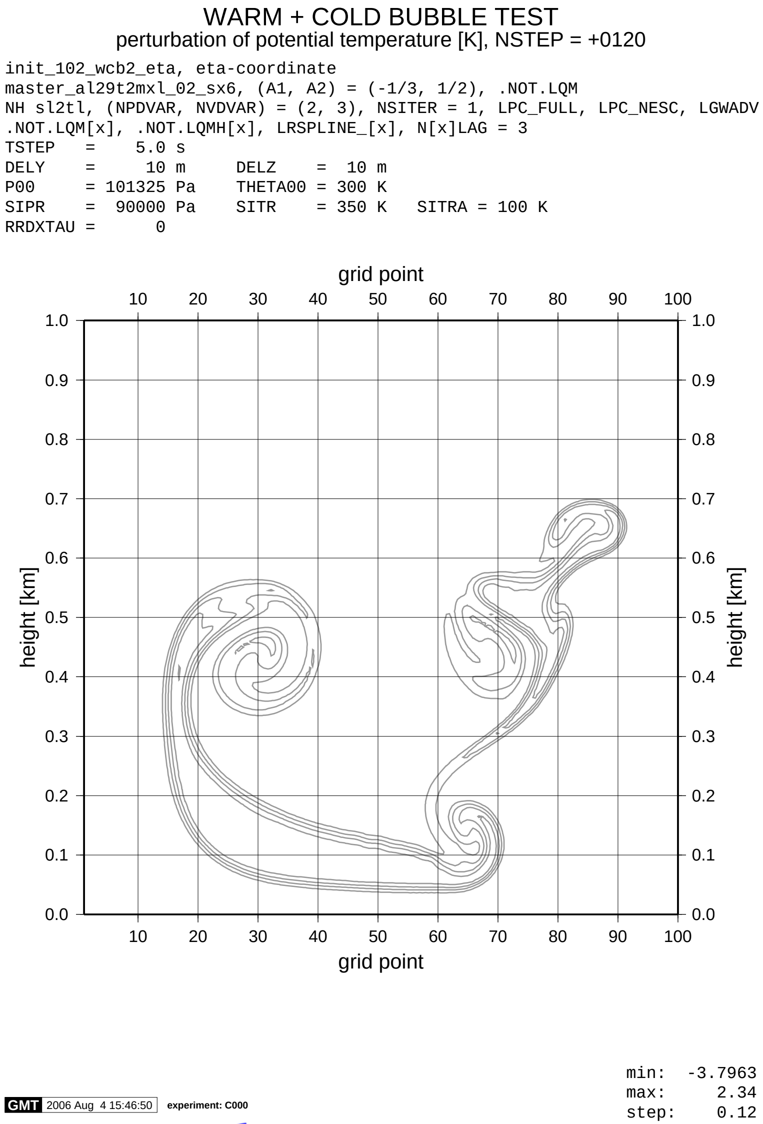
# New interpolators for SL

## Bubble test, after 10 minutes




- Lagrangian cubic

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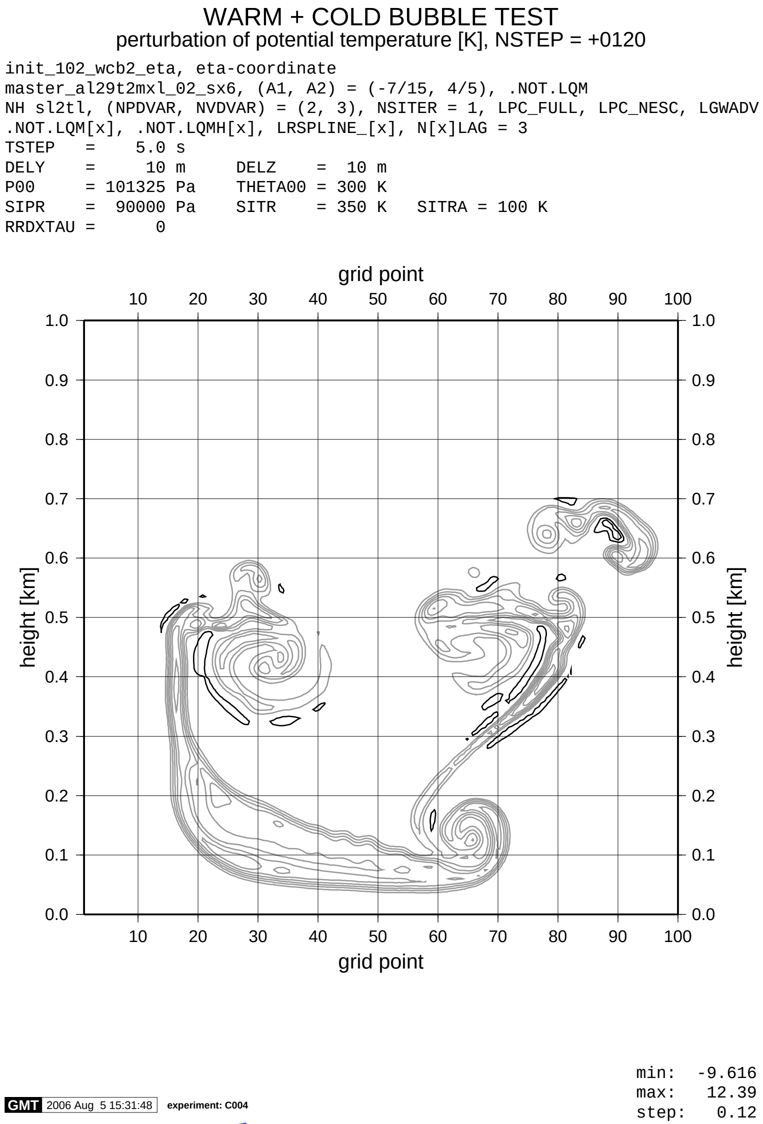


## Bubble test, after 10 minutes

- Lagrangian cubic
- Splines

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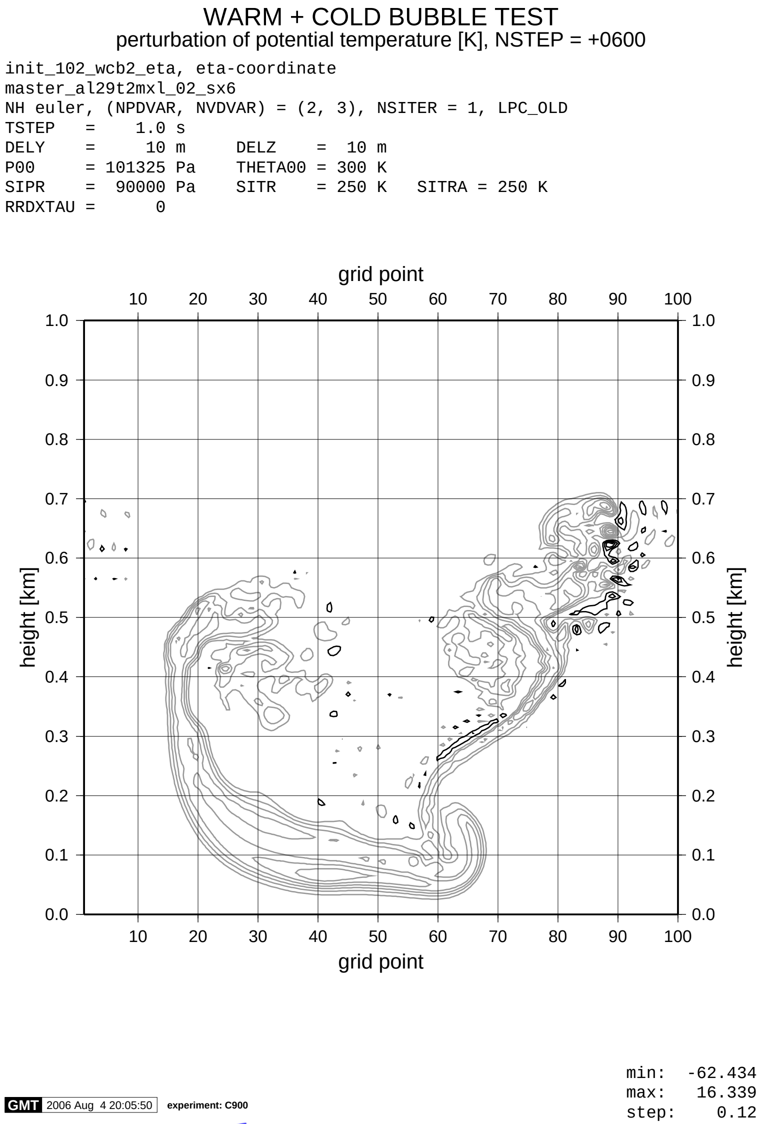
# New interpolators for SL




## Bubble test, after 10 minutes

- Lagrangian cubic
- Splines
- Eulerian adv.

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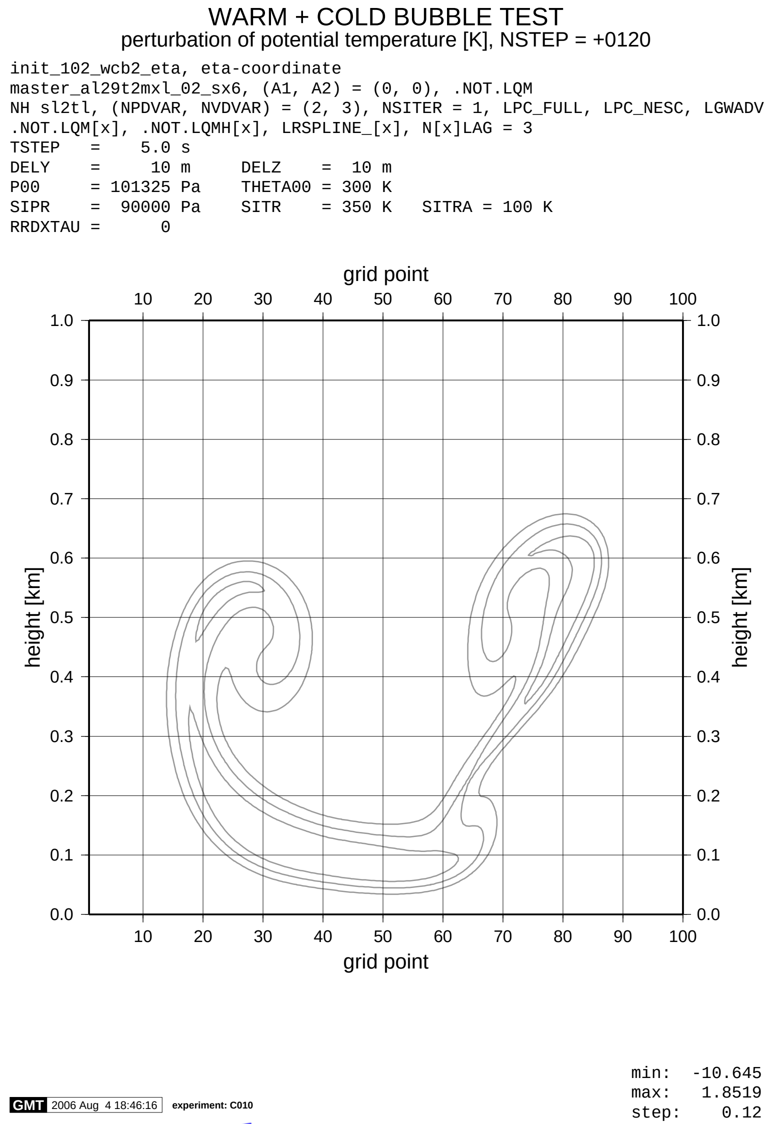
# New interpolators for SL




## Bubble test, after 10 minutes

- Lagrangian cubic
- Splines
- Eulerian adv.
- Linear

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# New interpolators for SL

Family of two parametric cubic interpolators

$$\begin{aligned} \mathbf{F(x,y)} &= \mathbf{w_0(x)y_0 + w_1(x)y_1} \\ &\quad \mathbf{+ w_1(1-x)y_2 + w_0(1-x)y_3} \end{aligned}$$

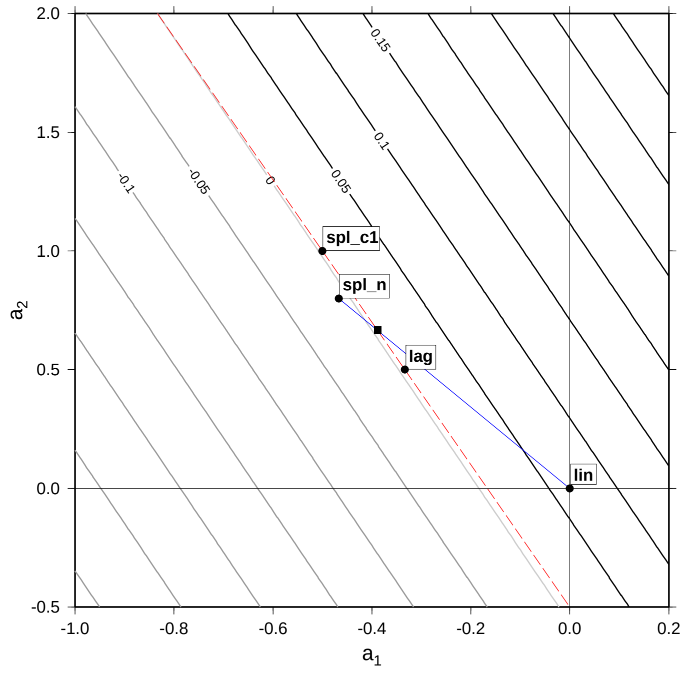
where

$$\begin{aligned} \mathbf{w_0(x)} &= \mathbf{a_1 x + a_2 x^2 - (a_1 + a_2)x^3} \\ \mathbf{w_1(x)} &= \mathbf{1 + (a_2 - 1)x - (3a_1 + 4a_2)x^2 + 3(a_1 + a_2)x^3} \end{aligned}$$

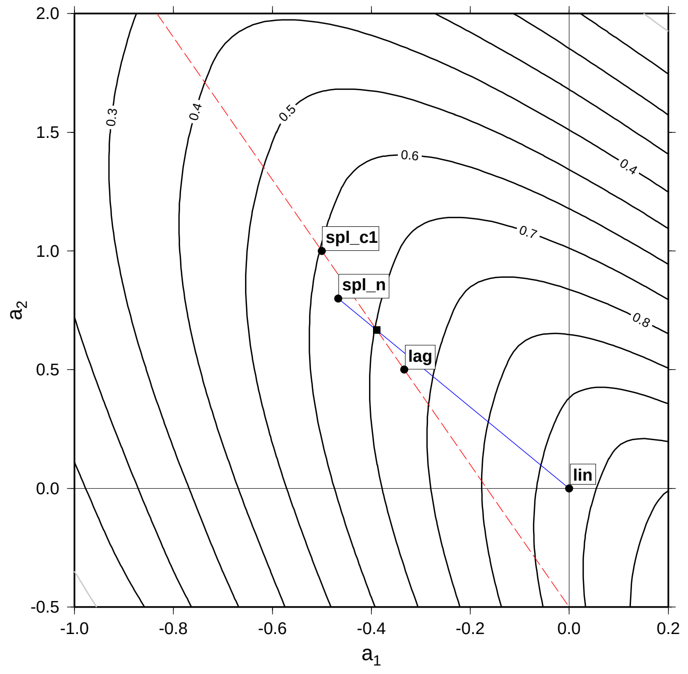
# New interpolators for SL

## Dimensionless damping rate

Damping factor for N = 100, m = 10




Damping factor for N = 100, m = 40



# TL/AD of the ALADIN SL

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## Convergence for the TL code:

$$\lim_{\epsilon \to 0} \frac{M(x+\epsilon\delta x) - M(x)}{\mathcal{M}'(\epsilon\delta x)}, \quad \epsilon = \epsilon_0 10^{\lambda}$$

| | Eulerian advection $\Delta t$=120s | SL advection $\Delta t$=450s |
|---|---|---|
| $\lambda$ = 0 | RAT = 0.4922389696335498E+00 | RAT = -.7944390364435365E+01 |
| $\lambda$ = -1 | RAT = 0.9500193013364470E+00 | RAT = -.4770497575992165E+00 |
| $\lambda$ = -2 | RAT = 0.9950083001890732E+00 | RAT = 0.6874108246125125E+00 |
| $\lambda$ = -3 | RAT = 0.9995037024689268E+00 | RAT = 0.9601433242017338E+00 |
| $\lambda$ = -4 | RAT = 0.9999513959612562E+00 | RAT = 0.9943026809878674E+00 |
| $\lambda$ = -5 | RAT = 0.1000315146923774E+01 | RAT = 0.9999531009073782E+00 |
| $\lambda$ = -6 | RAT = 0.1001714189087304E+01 | RAT = 0.1001665349367836E+01 |
| $\lambda$ = -7 | RAT = 0.1007310357741422E+01 | RAT = 0.1027349076274704E+01 |
| $\lambda$ = -8 | RAT = 0.1119233730823803E+01 | RAT = 0.8561242302289194E+00 |
| $\lambda$ = -9 | RAT = 0.5596168654119013E+01 | RAT = 0.4280621151144597E+01 |
| $\lambda$ = -10 | RAT = 0.0000000000000000E+00 | RAT = 0.0000000000000000E+00 |

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| $\lambda$ = -10 | RAT = 0.9970808134568164E+00 | RAT = 0.1032182685987080E+01 |

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# Physics-dynamics coupling

Work of: R. Hamdi (Be) and P. Termonia (Be)

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- This study was restricted to explicit, semi implicit and implicit physics parameterizations (over-implicitness not treated).

# Physics-dynamics coupling

## Possibilities to organize a time step

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- coupling of the physics to the dynamics at different positions (in space and time with respect to dyn.) on the SL trajectory
- computing the physics parameterization in a parallel or a fractional manner
- coupling the physics to the dynamics by updating the model state and using this for the dynamics, or computing the physics tendency and the dynamics tendencies separately and adding them to get the update, in other words to
  treat the physics/dynamics in a fractional or a sequential manner

# Physics-dynamics coupling

## A/A/A vs. SLAVEPP

| | A/A/A | SLAVEPP |
|---|---|---|
| phys. before/after dyn. | before | computed after and averaged |
| on SL traj. | at $t$ | at $t + \Delta t$ |
| parallel / sequential physics calls | parallel | sequential |
| parallel /sequential phys.- dyn. coupling | sequential | parallel |

# Physics-dynamics coupling

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- If the physics were treated in a semi-implicit way (in the A/A/A context) we would have the same stability and also second-order accuracy as in the SLAVEPP approach. This is maybe not practical but nevertheless a nice surprise because it means that *(in the 1d model) one could get the same benefits of the time step reorganization, by an internal reorganization of the physics*.

# Physics-dynamics coupling

## Outcome for A/A/A

- If both forcing and diffusive processes are present, a SLAVEPP kind of time step becomes superior to the A/A/A one *IF* the diffusive processes are coupled *LAST*. This will also lead to a more accurate steady state and less climate drift.

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# Physics-dynamics coupling

## Outcome for A/A/A

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- A code reorganization is expected to yield benefits.
- There seems to be no better option with respect of phys-dyn coupling to increase the existing stability of the physics in the A/A/A framework.
- Publication with the detailed guidelines is in preparation (manuscript can be obtained from *piet.termonia@oma.be*)

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Work of: F. Voitus (Fr) and P. Termonia (Be)

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- This is related to a deeper question: “Can one impose LBCs independently from the details of the dynamics integration scheme?”
- In a spectral model we are forced to address this question, but in a gridpoint model maintained in a huge collaboration with different kinds of researchers working together, this will have to be addressed too.

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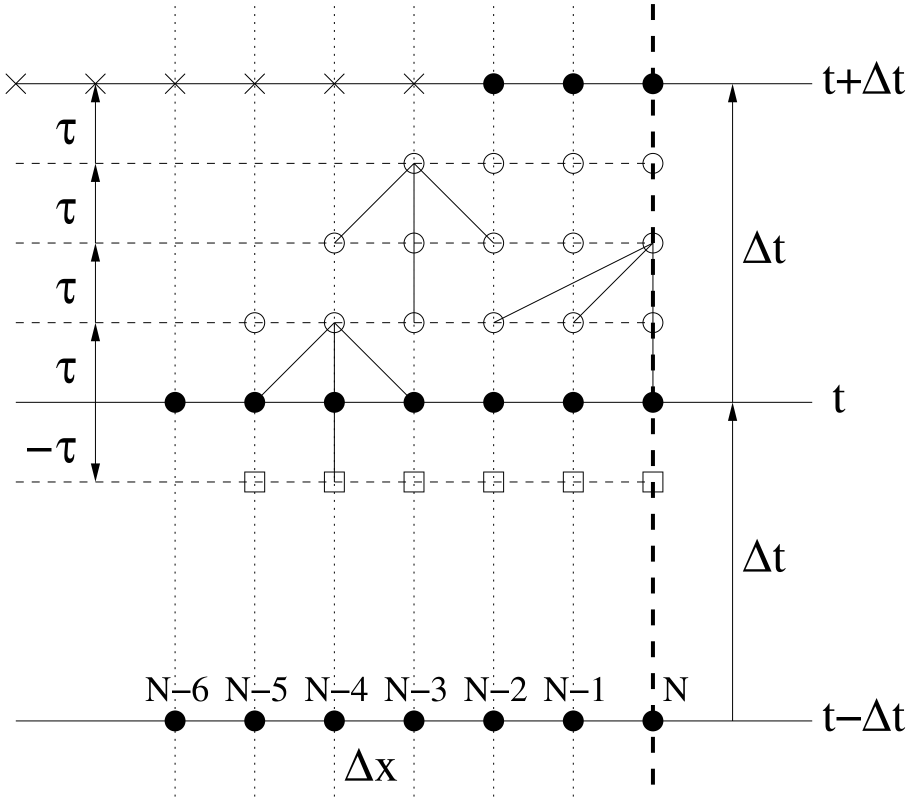
- Proposal: rely on sub-stepping

# Transparent LBCs in spec. models

## Is it feasible?

Tests with a leapfrog scheme with following space-time structure



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## First test in Shallow water model

- Inside the domain (crosses): SISL 2TL
  Near the boundary to compute 3 points at $t + \Delta t$ (solid dots): leapfrog Asselin or leapfrog trapezoidal by sub-stepping with interval $\tau$

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- This allows to have transparent LBCs at wave Courant number 5.6 (extra research is going on to get higher Courant nrs.) $\Rightarrow$ The idea is not entirely crazy.
- The problem is being replaced to data flow...: We need an extra large stencil near the boundary (solid dots at $t$).