SEMI-LAGRANGIAN ADVECTION SCHEME WITH CONTROLLED DAMPING - - A NEW FEATURE IN ALADIN

FILIP VÁŇA

Introduction

Scheme definition and properties

Scheme potential problems

Demonstration of the SLHD scheme skills

Conclusion

Horizontal diffusion in atmospheric models

- **Formal mathematical reason**
  avoid the hyperbolic kind of model equations
  $\Rightarrow$ **with current models no need to take care about...**

- **Parameterization of the physical processes**
  horizontal turbulence and the molecular exchange;
  when $\triangle x \approx$ 9.5 km its contribution to u, v is of 10^{-7}–10^{-3} m/s
  $\Rightarrow$ **non-linear operator using flow field characteristics**

- **Numerical filter**
  removing the accumulated energy from the end of a model resolved spectrum and filtration of the numerical noise;
  when $\triangle x \approx$ 9.5 km its contribution to u, v is of 10^{-2}–10^{0} m/s
  $\Rightarrow$ **linear operator of $K\nabla^r$ kind is sufficient**

SLHD scheme definition

$$\frac{d\Psi}{dt} = \mathcal{R} + \mathcal{F}$$

3TL sL:

$$\Psi(\vec{x}, t + \Delta t) = \Delta t \mathcal{R}(\vec{x}, t) + \left[\underbrace{\Psi(\vec{x} - 2\vec{\alpha}, t - \Delta t) + 2\Delta t \mathcal{F}(\vec{x} - 2\vec{\alpha}, t - \Delta t) + \Delta t \mathcal{R}(\vec{x} - 2\vec{\alpha}, t)}_{I} \right]$$

$$I = (1 - \kappa) I_A + \kappa I_D = I_A + \kappa (I_D - I_A)$$

$$\kappa = F(d, \Delta x, \Delta t)$$

$$d = \sqrt{\left(\underbrace{\frac{\partial u}{\partial x} - \frac{\partial v}{\partial y}}_{d_T} \right)^2 + \left(\underbrace{\frac{\partial u}{\partial y} + \frac{\partial v}{\partial x}}_{d_S} \right)^2}$$

SLHD properties

Comparison of the SLHD scheme characteristics with the ALADIN spectral linear diffusion parameters $\mathcal{H}$ and r:

General form of linear diffusion:

$$\left.\frac{\partial \Psi}{\partial t}\right|_{\text{diff}} = -(-1)^{(r/2)} K \nabla^r \Psi$$

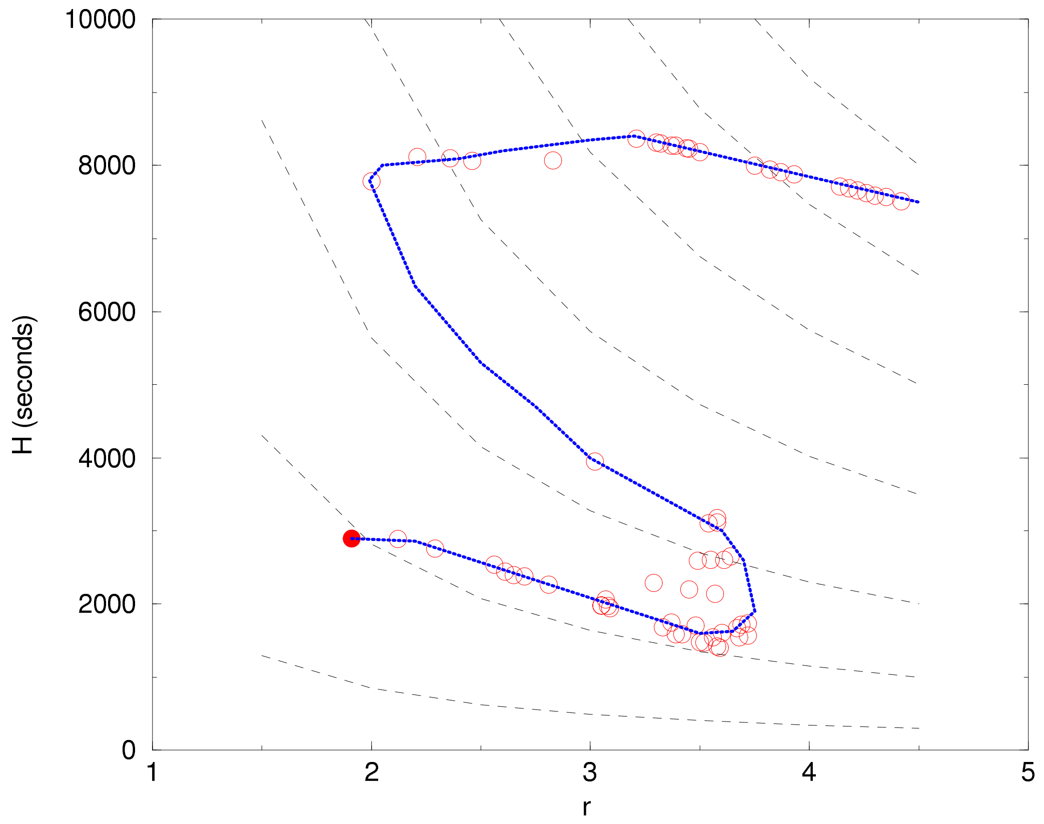
In ALADIN:

$$K = \Omega h_\Psi \left[\left(\frac{-1}{2\pi} \right) \left(\frac{L_x^2}{\mathcal{M}^2} + \frac{L_y^2}{\mathcal{N}^2} \right) \right]^{r/2} \exp\left(-\frac{i\pi r}{2} \right) G(l)$$

$$\mathcal{H}_\Psi = \frac{1}{\Omega h_\Psi}$$

SLHD properties II.

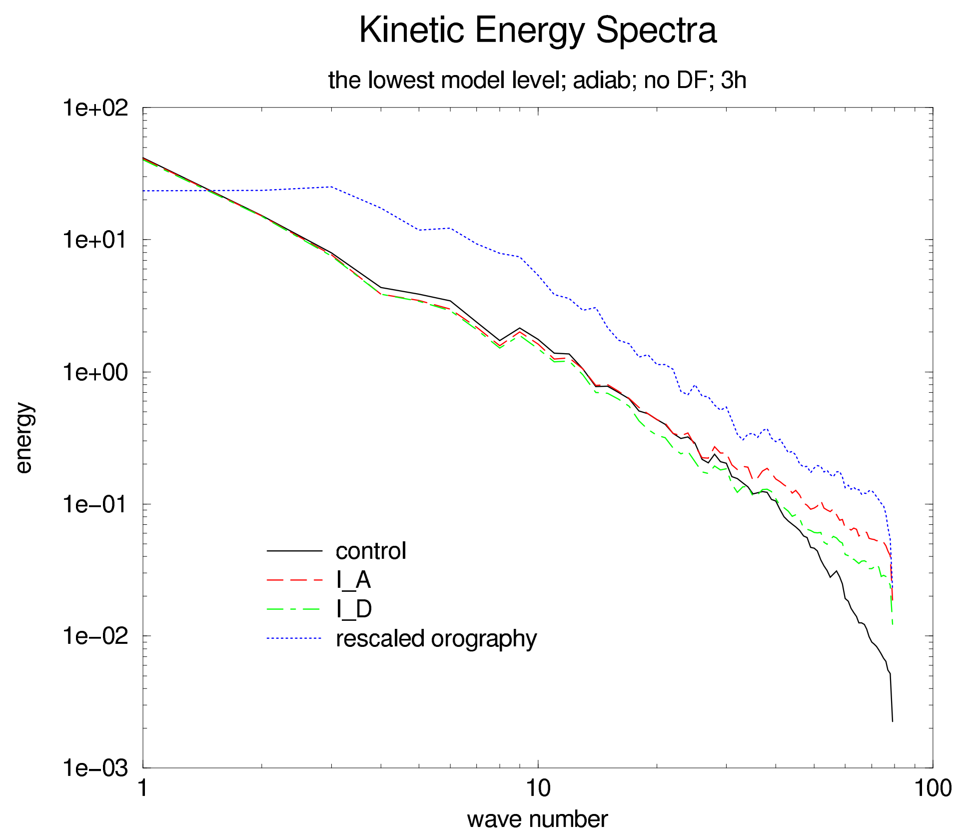
Characteristic curve of the SLHD expressed in equivalent $\mathcal{H}$ and r parameters (obtained from the idealised 3D experiment).



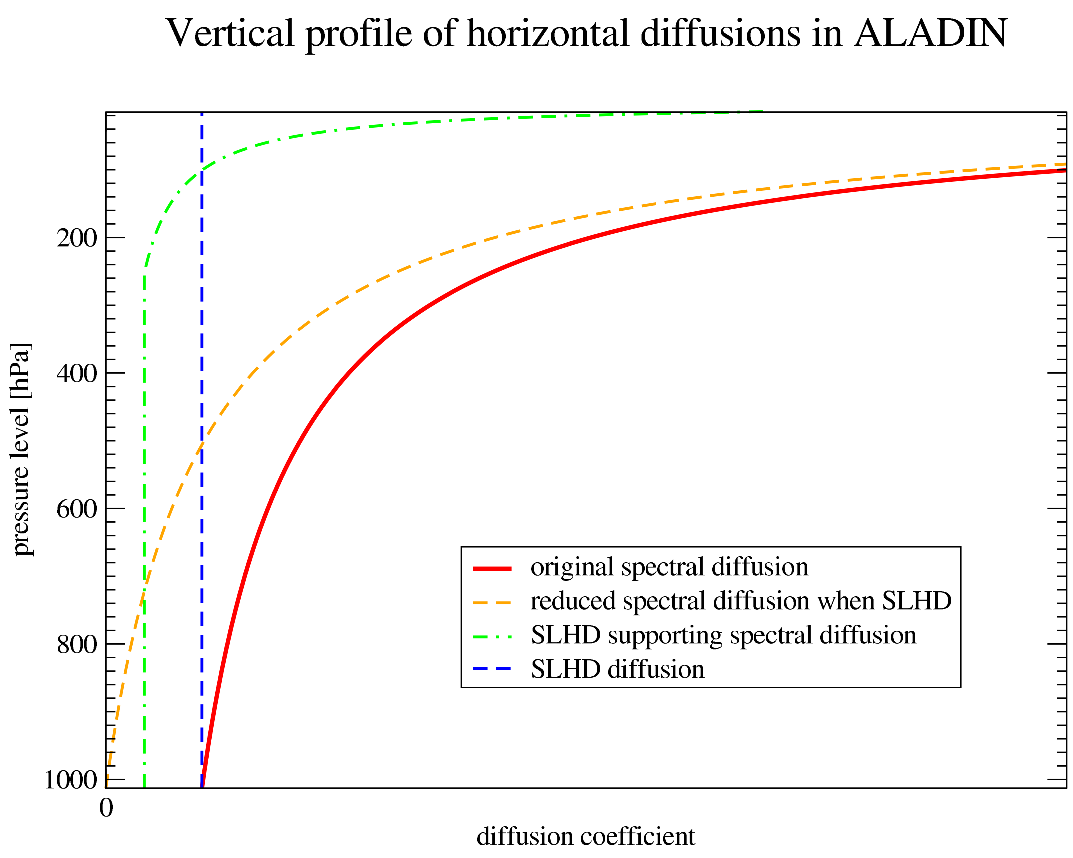
SLHD properties III.

Real case

$$\left.\frac{\partial\Psi}{\partial t}\right|_{diff} = \mathcal{D}_{SLHD}\left[\Psi(\vec{x}, t+\Delta t) - \Delta t\mathcal{R}(\vec{x}, t)\right]$$



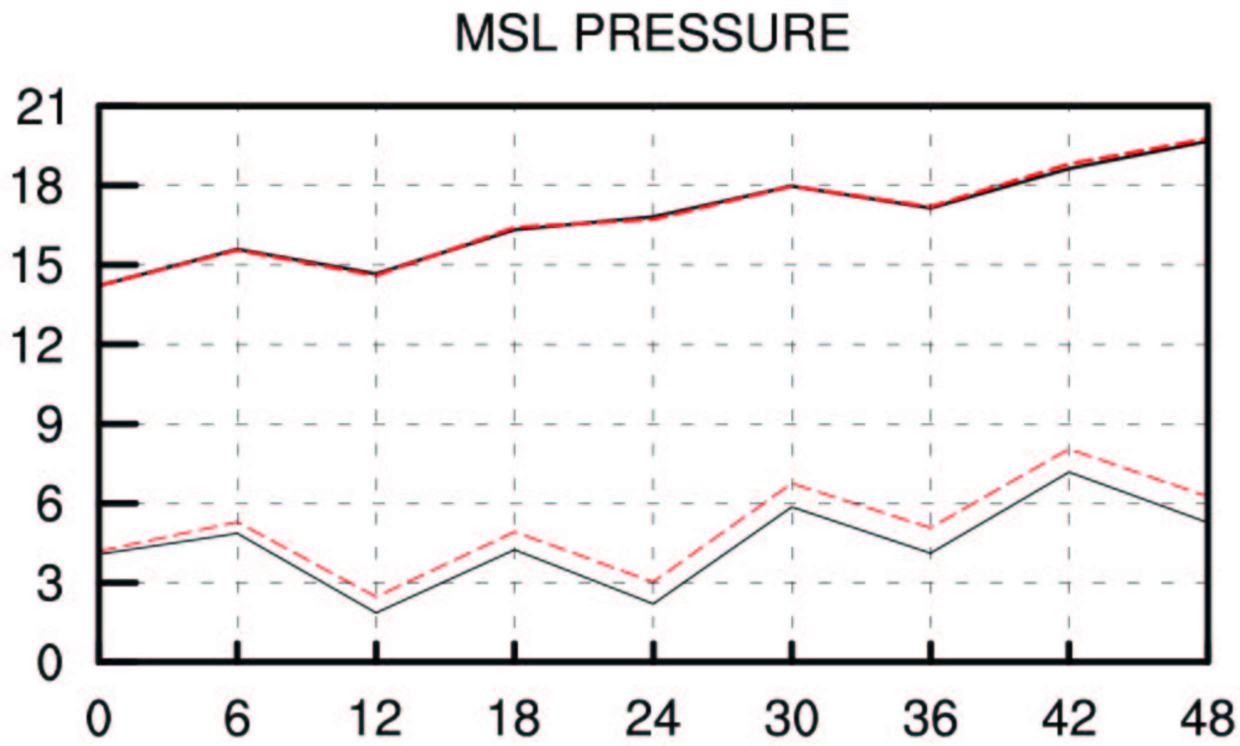
SLHD in ALADIN



SLHD properties IV.

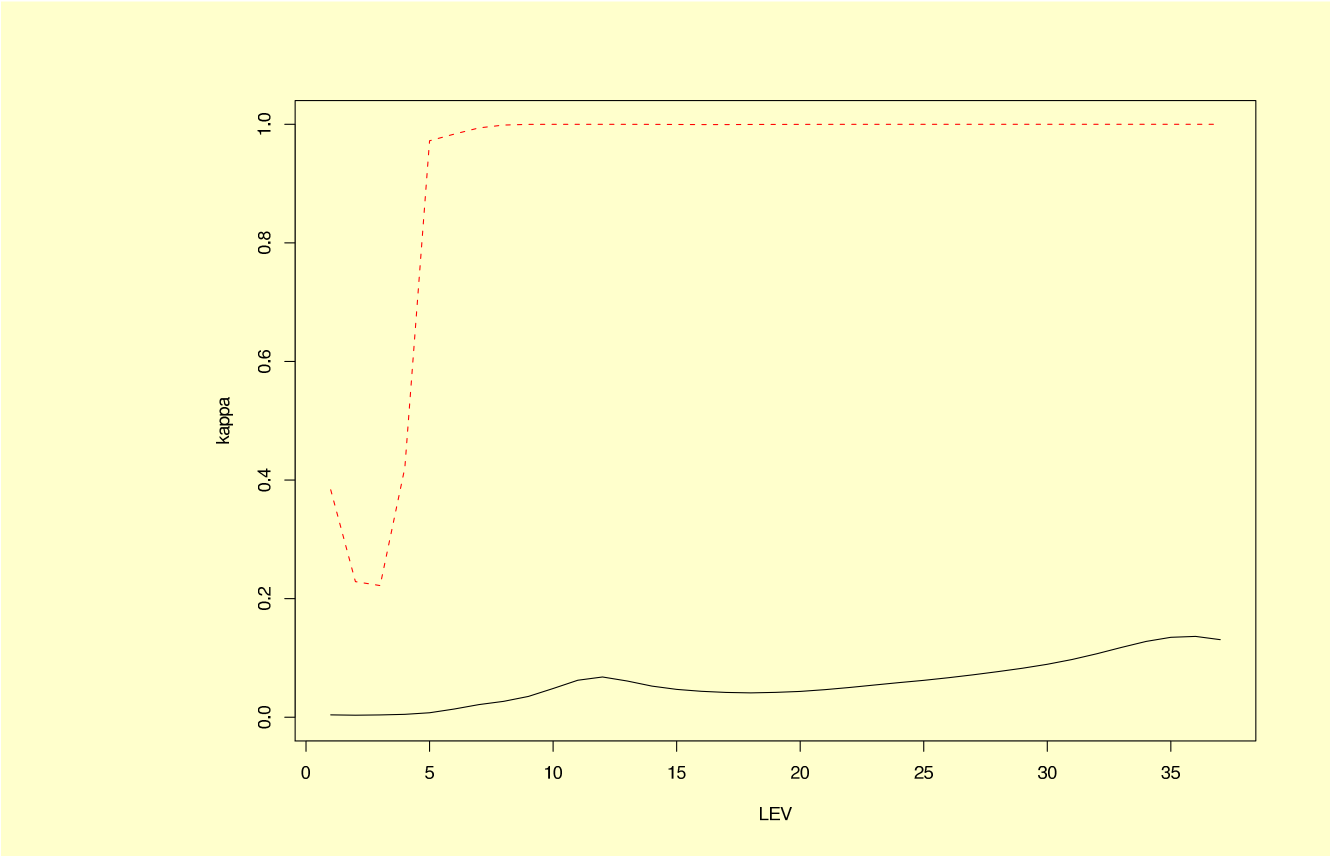
Evolution of MSL pressure RMSE and BIAS
with forecast range

Parallel test, 19 days period



SLHD properties V.

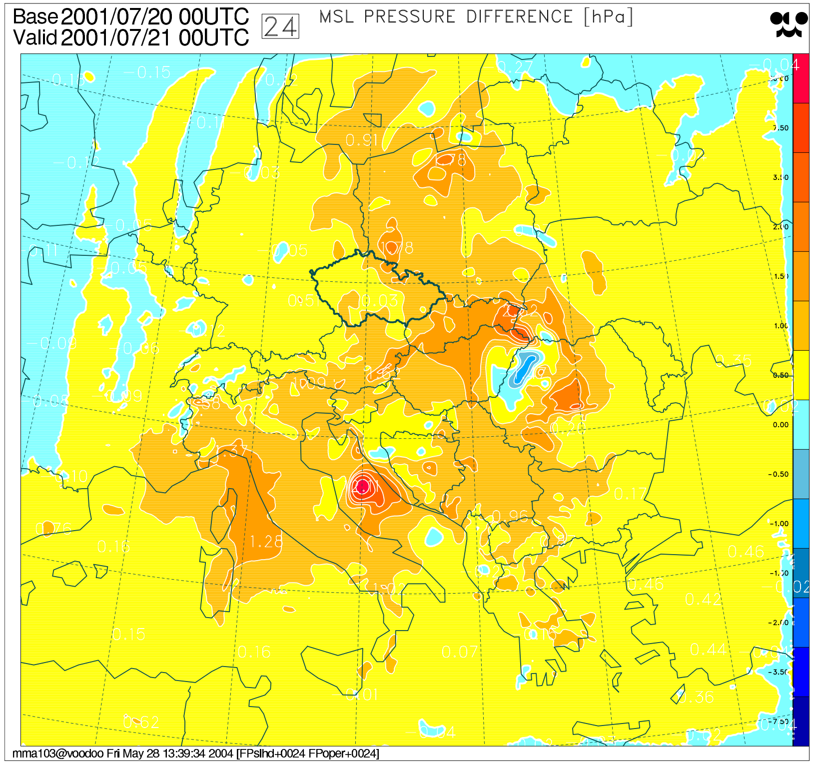
Average and maximum values of κ during the model integration

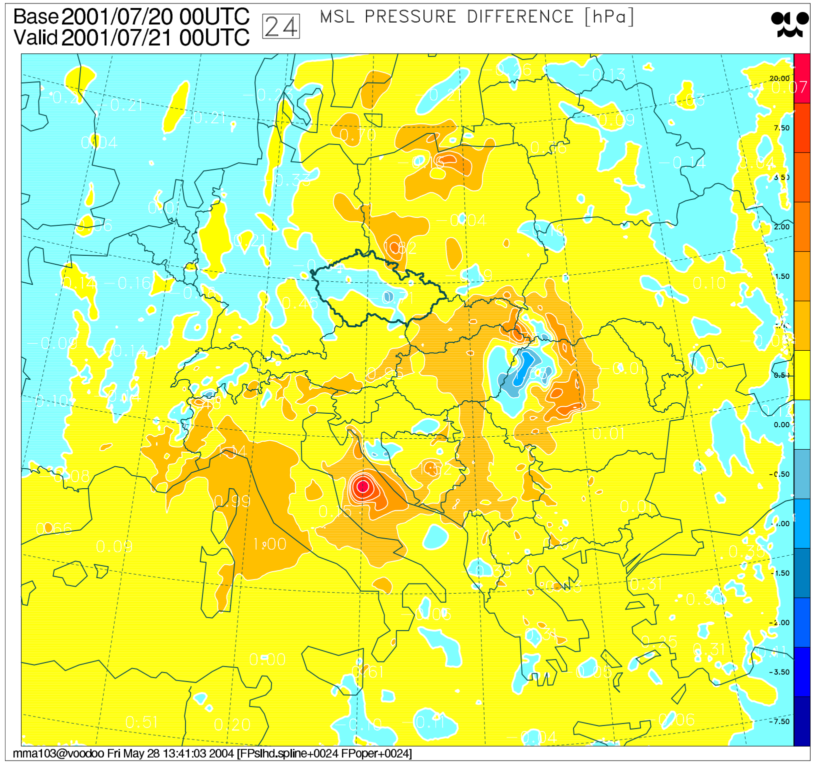


Solution for MSL pressure BIAS

Lagrangian cubic interpolation

$\Rightarrow$ Natural 4 points cubic spline





SLHD potential problems

- Can the SLHD scheme influence a distribution of S-L trajectories origin points?

- Is the scheme performance dependent on a given distribution of S-L trajectories origin points?

- Can the non-uniform smoothing of a diffusive SLHD interpolator be responsible for a small scale noise generation?

Distribution of the S-L origin points distances from the closest grid point (2D)

With SLHD

Number of diagnosed items : 14 315 239

Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
6.077e-05	2.040e-01	3.331e-01	3.289e-01	4.519e-01	7.071e-01

Quantile of 1% cases: 0.03697184

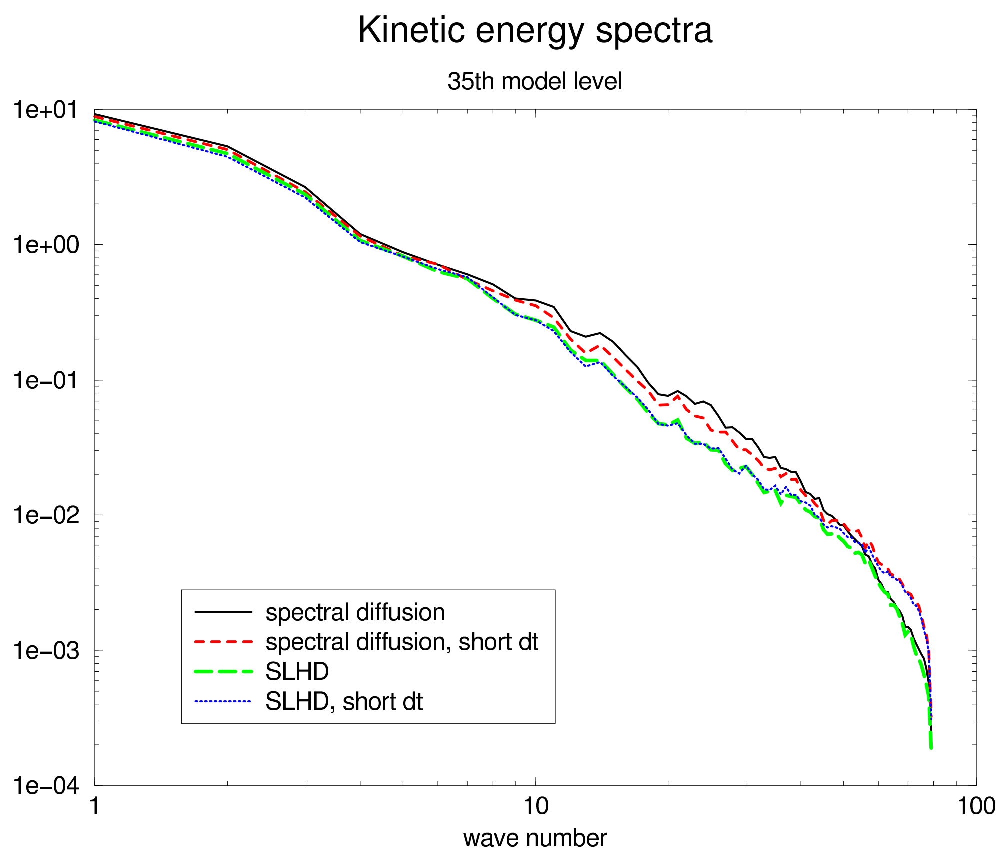
Reference

Number of diagnosed items: 14 315 288

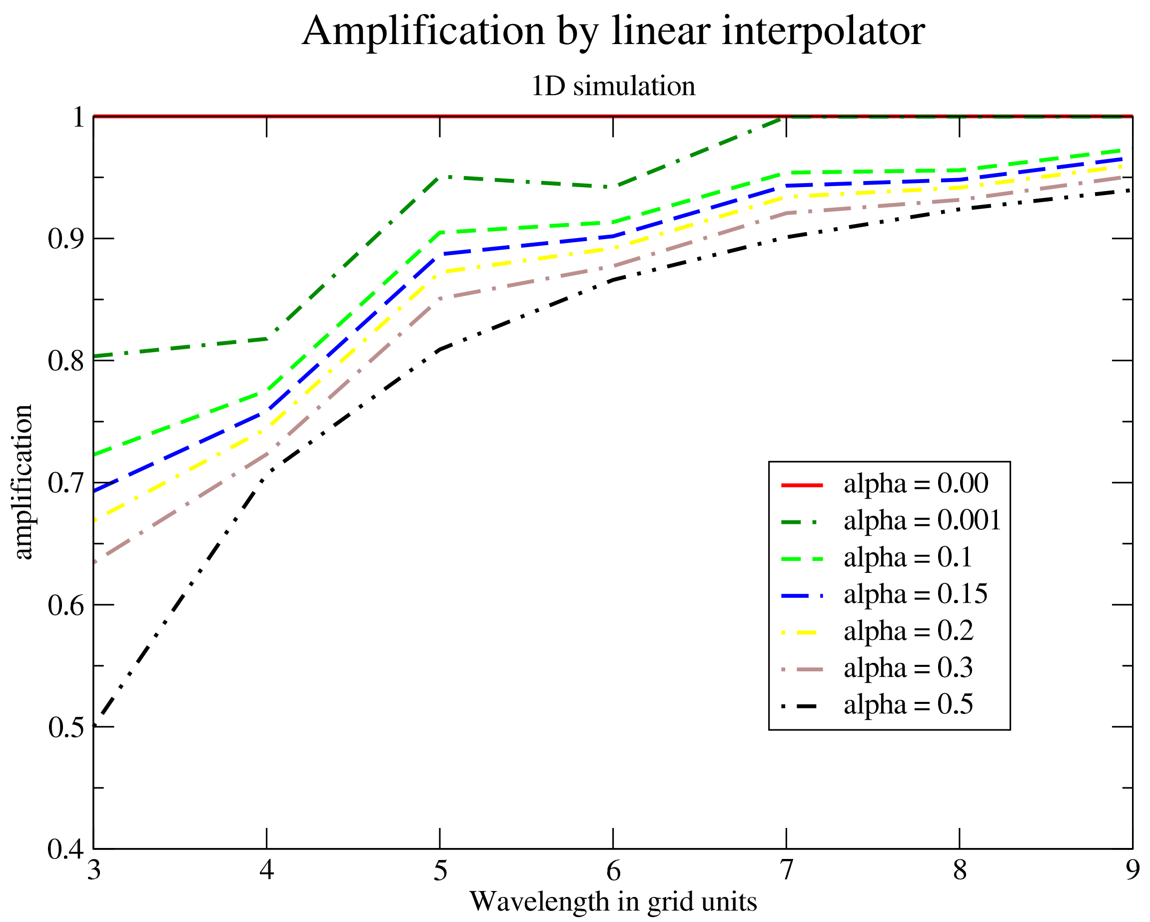
Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
9.021e-05	2.041e-01	3.332e-01	3.290e-01	4.520e-01	7.069e-01

Quantile of 1% cases: 0.03700731

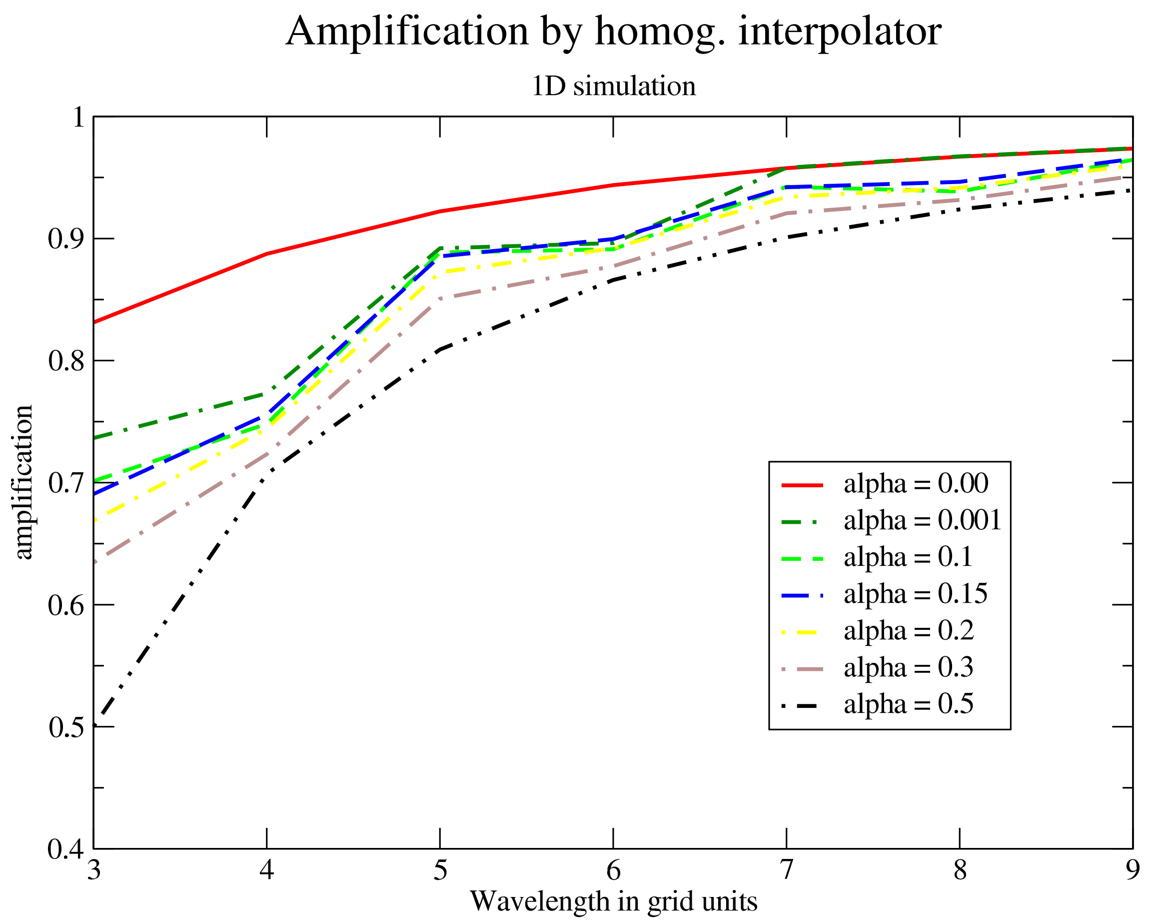
Influence of the S-L origin points distribution to the SLHD performance



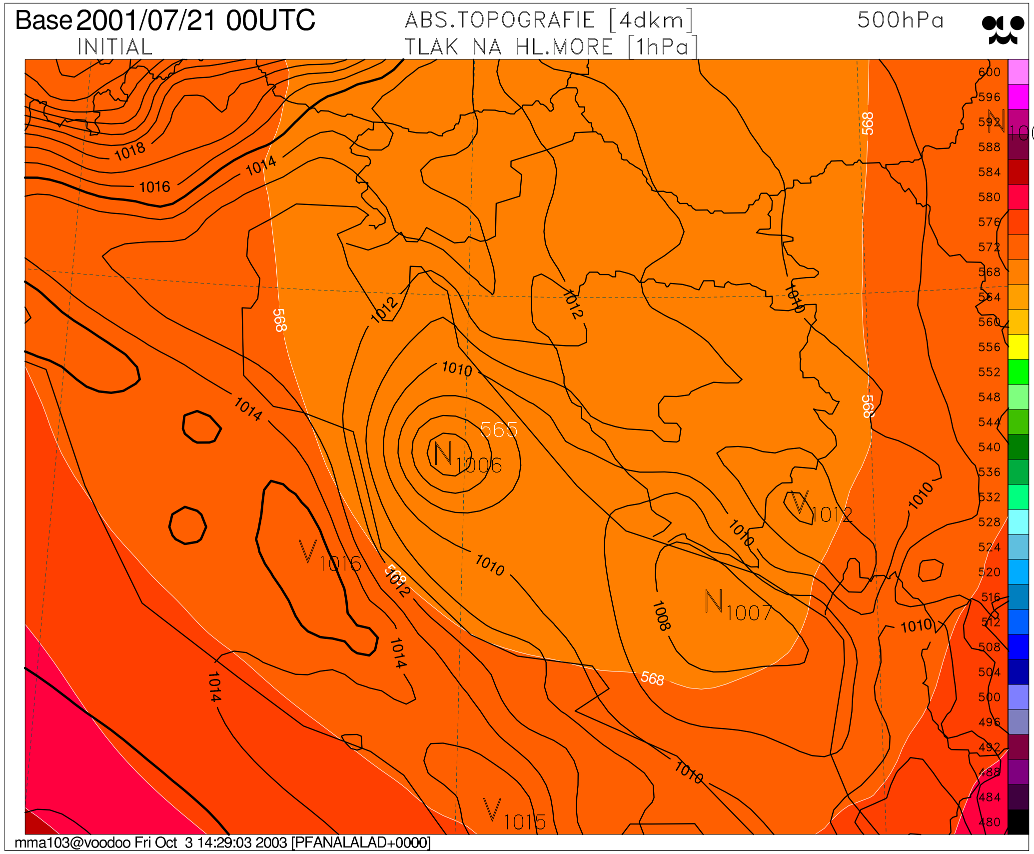
Amplification factor of the diffusive interpolator with respect to the S-L origin point distance from the grid point



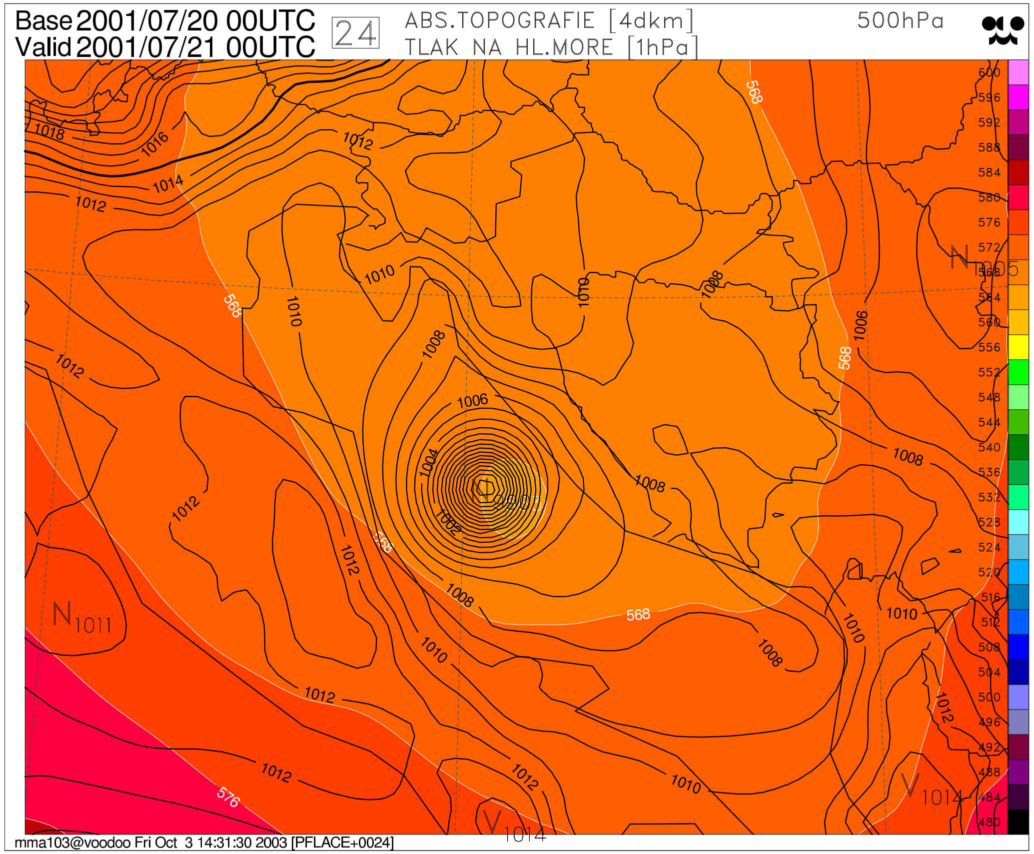
Amplification factor of the diffusive interpolator with respect to the S-L origin point distance from the grid point



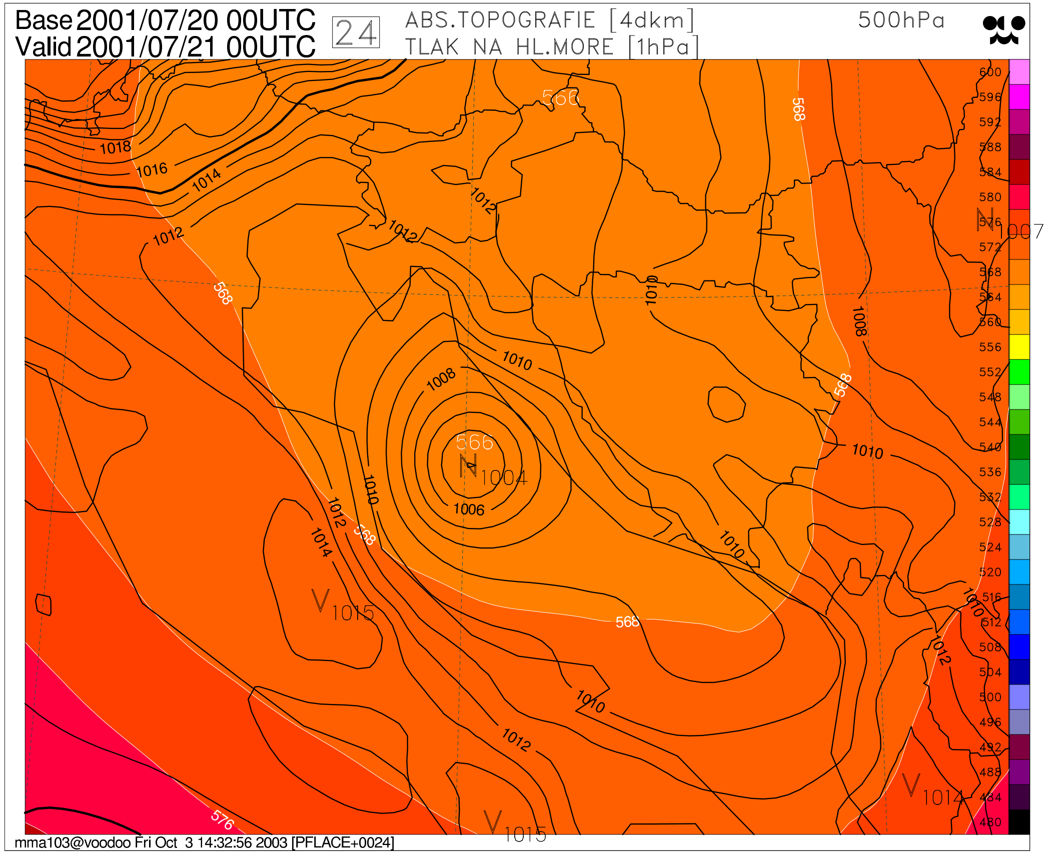
Adriatic storm, ALADIN/LACE analysis



Adriatic storm, operational forecast



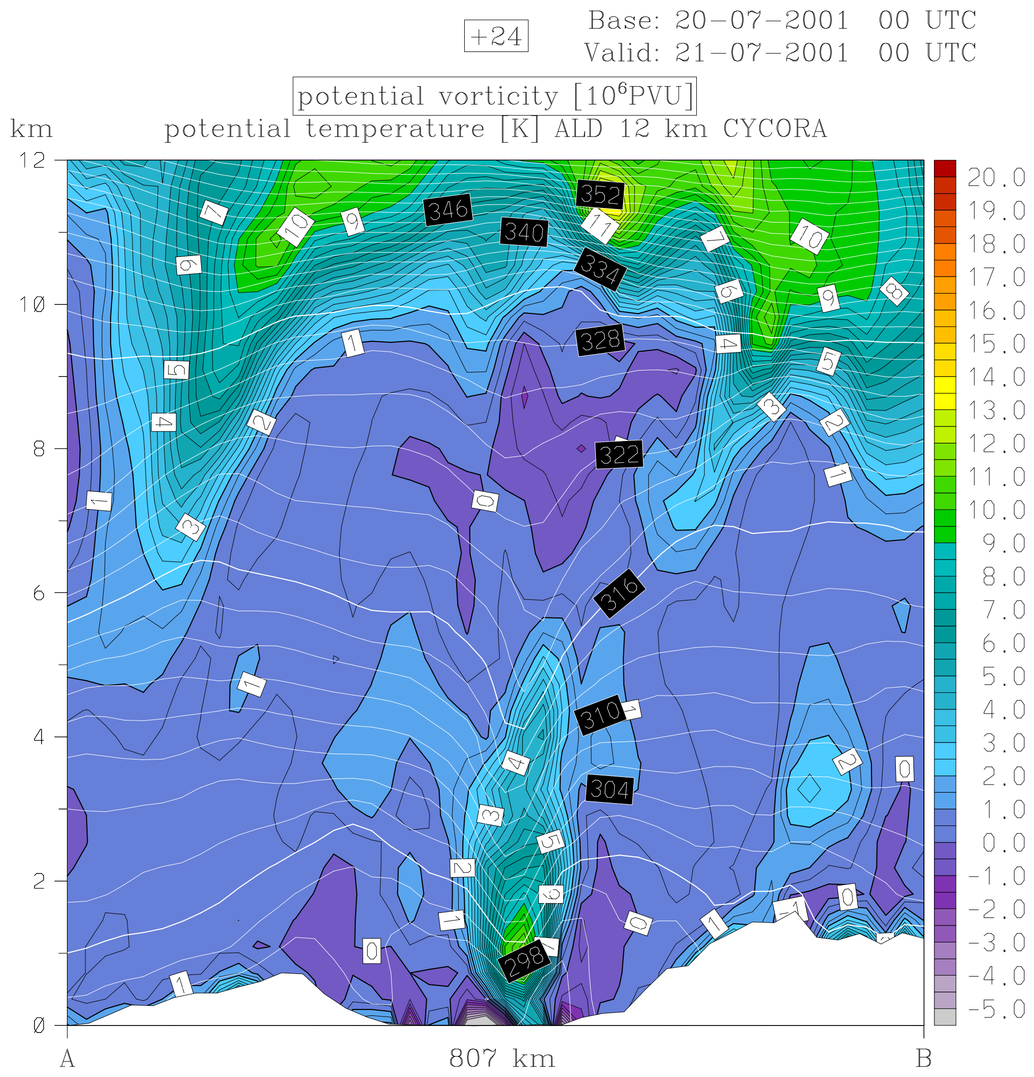
Adriatic storm, SLHD



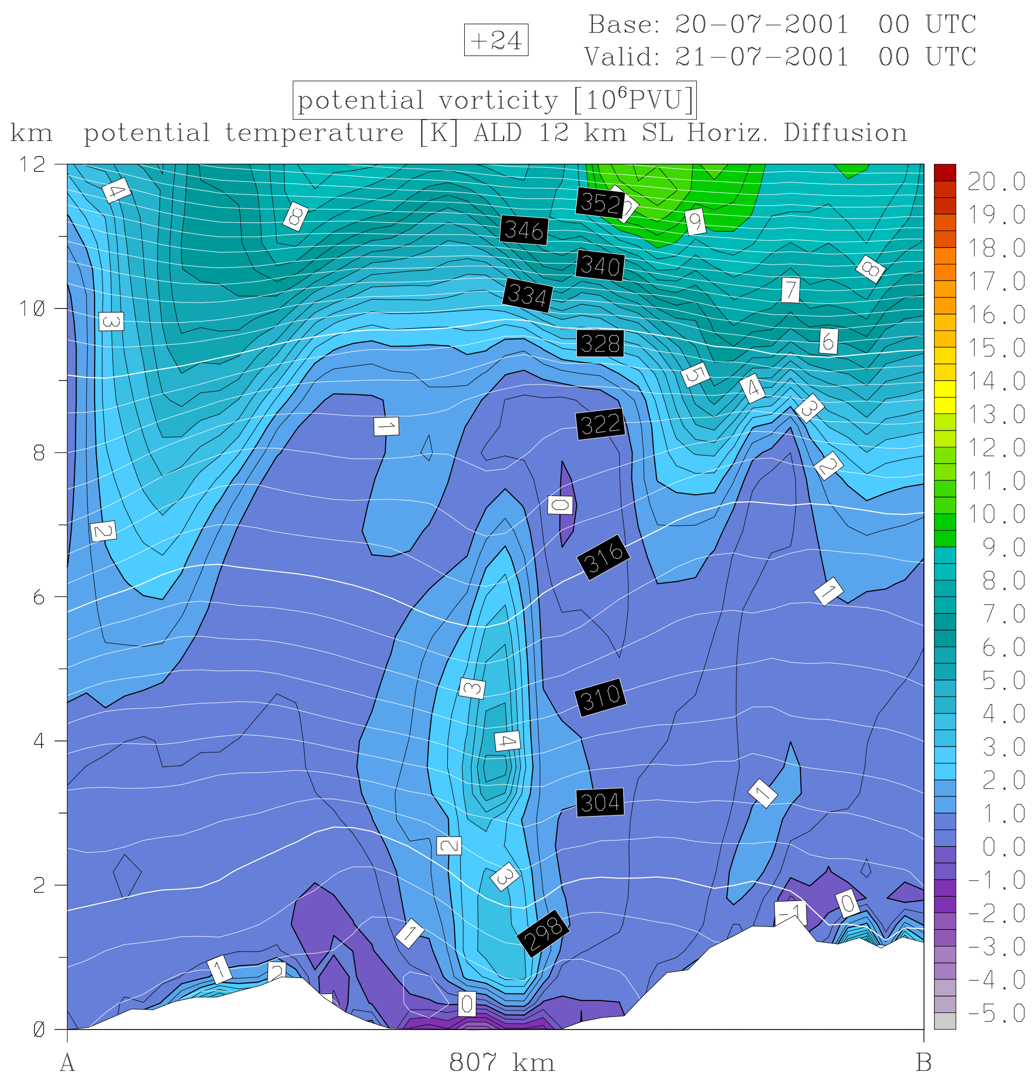
Adriatic storm, vertical cross-section line

ASCS – Aladin Space Cross Section

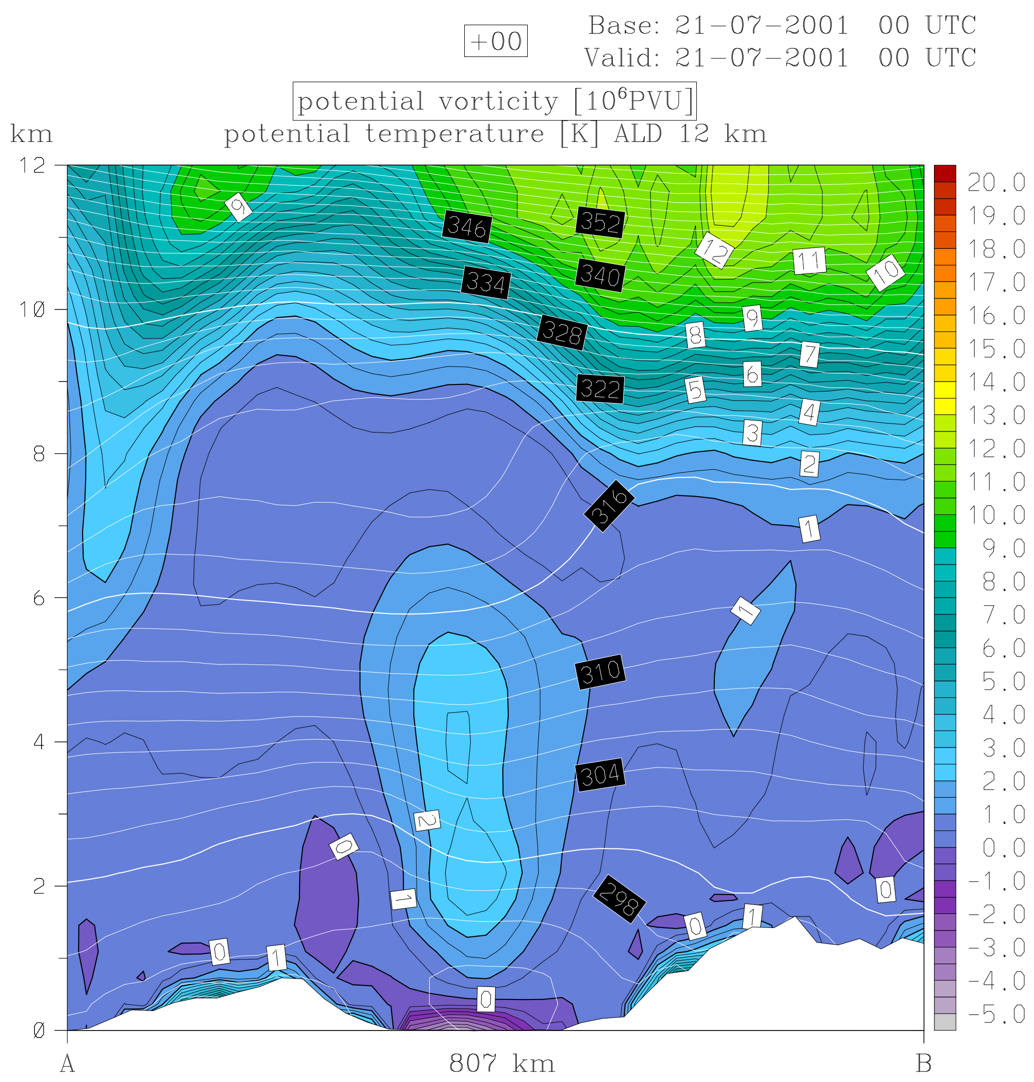
Adriatic storm, operational forecast



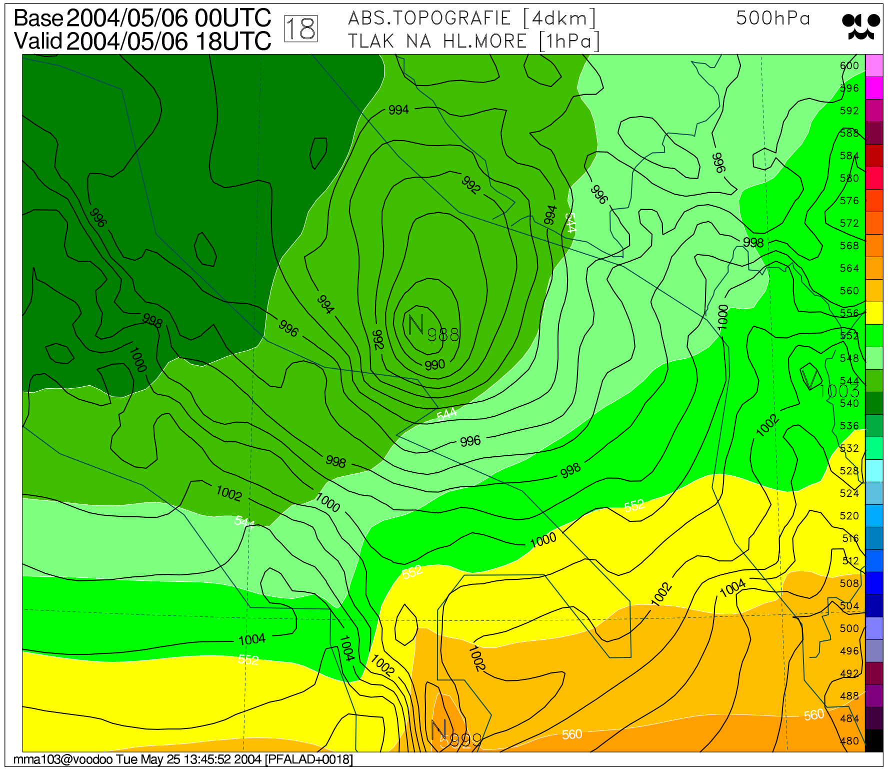
Adriatic storm, SLHD

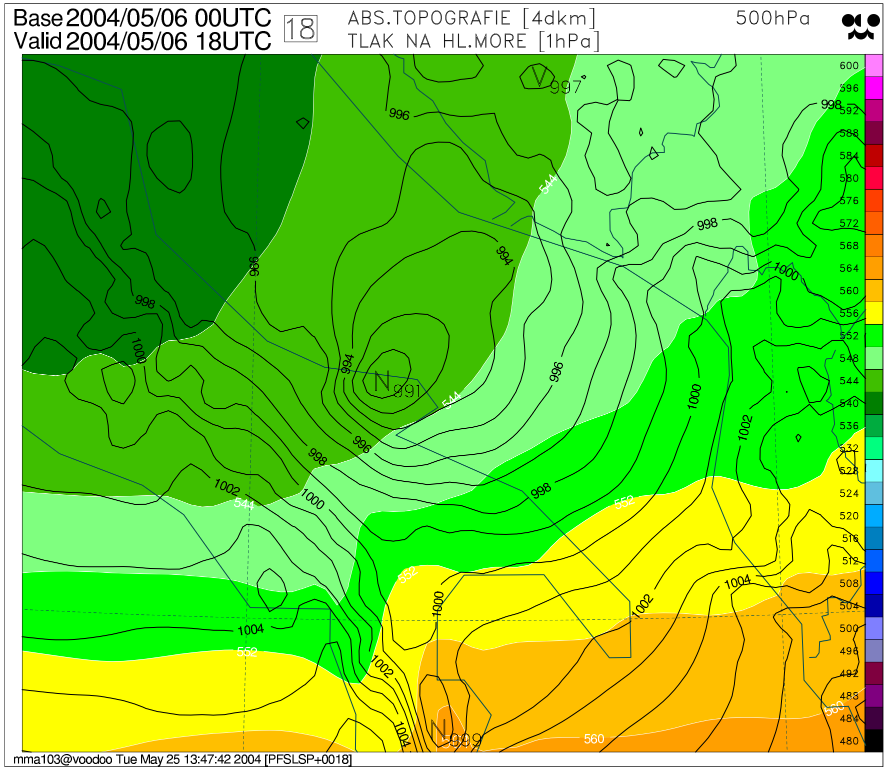


Adriatic storm, analysis



Adriatic storm, #2





Conclusion

- General advantages of the SLHD scheme
  - Trivial implementation
  - Cheap (relatively) **non-linear** diffusion
  - Stable
  - Turns damping side-effect of the S-L advection to useful tool

- Advantages of the SLHD scheme for a spectral model
  - Physically realistic
  - Real horizontal diffusion
  - Ability to control any prognostic field
  - Simple treatment in case of a non-uniform model mesh
  - Numerical security

- Weak points
  - To control a noise generated by model orography causes some difficulty
  - Only one degree of freedom for tuning

SLHD in ALADIN

- available for testing purposes since CY28T1
- validation is required, debugging of DFI
- studies focused on mountains are expected
- retuning of the scheme scale (in)dependence