Regional Cooperation for
Limited Area Modeling in Central Europe

LACE
nwp central europe

LACE – DYNAMICS & COUPLING

Petra Smolíková (CHMI), Jozef Vivoda (SHMI), Radmila Brožková, Ján Mašek (CHMI), David Lancz (OMSZ)
Hirlam coop.: Juan Simarro, Alvaro Subias (AEMET)

DHMZ SHMU OMSZ ZAMG ROMANIA ANM

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Summary

1. **Finite element method in vertical discretization of NH model**

   - cooperation with HIRLAM colleagues

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3. **Physical tendency of vertical velocity in NH**

Summary

1. Finite element method in vertical discretization of NH model
   - cooperation with HIRLAM colleagues
3. Physical tendency of vertical velocity in NH
5. Scale adaptive horizontal diffusion - SLHD tuning for seamless approach

1. VFE in NH (J.Vivoda, A.Subias, J.Simarro)

1. To test the NH VFE implementation in the **2D vertical plane** standard tests (non-hydrostatic flow over idealized orography, potential flow, Straka test of density current)
2. To prepare **real case study** and show that the proposed method is stable and robust
3. To show that the proposed iteration method for Helmholtz equation solution **converges** and only few iterations are enough to get satisfactory results
4. To **clean** the existing code from obsolete options
5. To **phase** the existing development to the cycle CY40T1
6. To adapt the designed FE method for the use in **global model**, to check if the iterative SI-solver is compatible with the use of variable map factor (for stretched version of the global model)

1. VFE in NH (J.Vivoda, A.Subias, J.Simarro)

9. To define **eta levels in the maxims of splines**, to define knots from the predefined full levels with the consequence of splines having maxims close to full levels for the computed knots sequence (projection operator diagonal, less splines overlapping)
10. To define **invertible operators** for derivation and integral and to implement them into the model code
11. To **study the accuracy** of these invertible operators aiming on clear proof of the advantage of FE discretization over FD one (comparison of numerical and analytical normal modes in the simplified framework)
12. Enable an arbitrary choice of **the spline order** and test the method with high orders
13. To study and implement **pure FE definition of the vertical Laplacian**; just semi-FE definition is used up to now, in which top and bottom values are replaced with their FD counterparts

1. VFE in NH (J.Vivoda, A.Subias, J.Simarro)

Current status: there is a working implementation of the FE method in the vertical discretization of the NH model in the cycle CY40T1

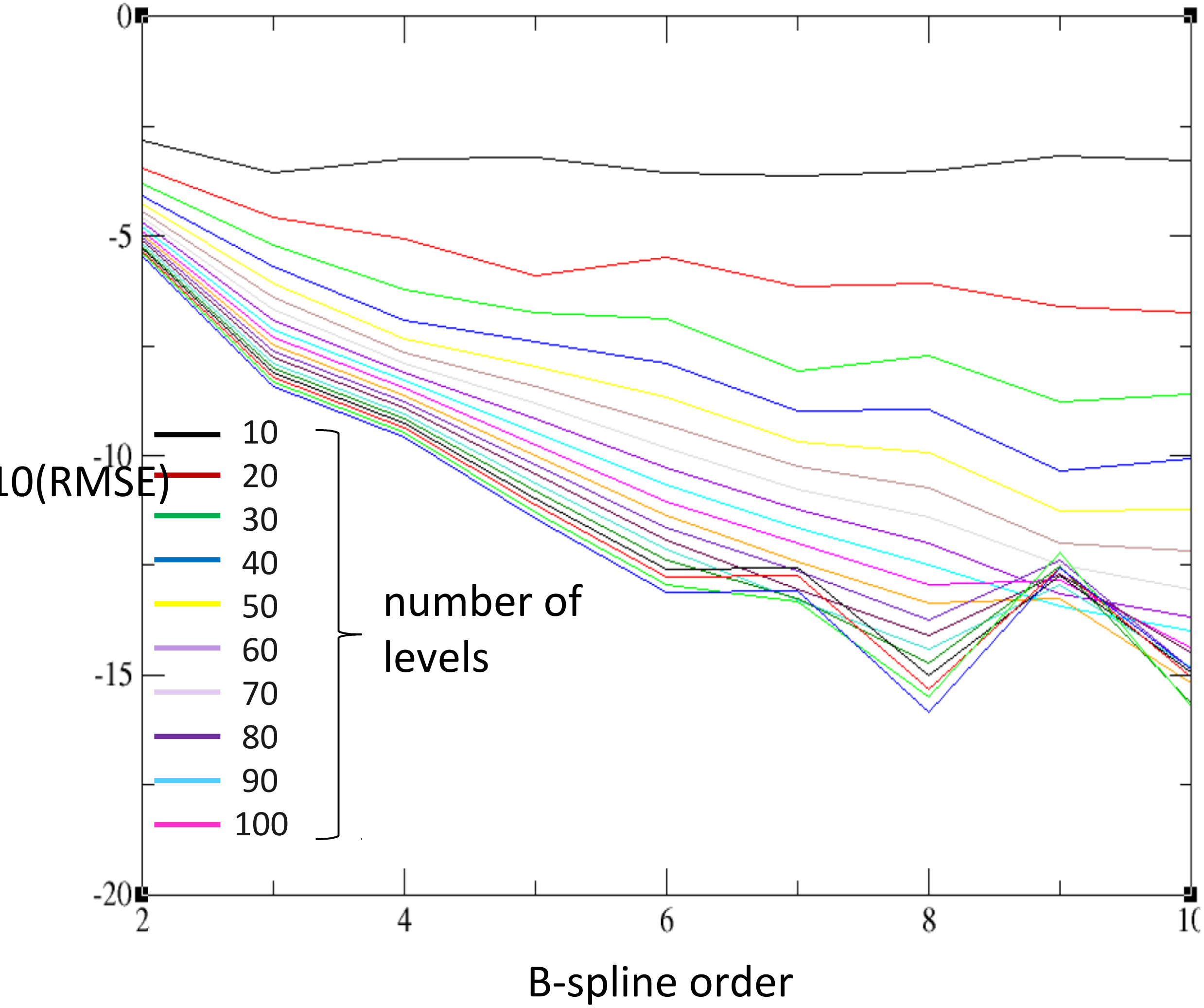
Important question: **Why this implementation works?**

Which choices of parameters and methods are crucial and which are arbitrary?

Especially this concerns the following problems:

1. The choice of **boundary conditions** for vertical operators
2. Fulfilment of **constraints (C1) and (C2)** for vertical operators
3. The choice of **vertical levels** in connection to the choice of **knots** for spline definitions
4. The sufficient and necessary conditions posed on **eigenvalues of vertical Laplacian** operator for stability of the scheme

1. VFE in NH (J.Vivoda, A.Subias, J.Simarro)



Impact of the B-spline order:

- applied on smooth function satisfying bc
- higher resolution beneficial up to a saturation
- higher B-spline order beneficial up to 6
- even numbers more suitable then the odd ones (cubic splines have order 4)

1. VFE in NH (J.Vivoda, A.Subias, J.Simarro)

- Stability reasons $\Rightarrow$ **vertical divergence *d*** in spectral calculations (SI scheme)
- Accuracy reasons $\Rightarrow$ **vertical velocity *w*** in GP calculations (NL model and advection, under LGWADV=T)
- **Transformations** (ones per time step) by vertical operators $\boldsymbol{I},\boldsymbol{D}$

  Derivative $\boldsymbol{D} : w \rightarrow d$ after GP calculations

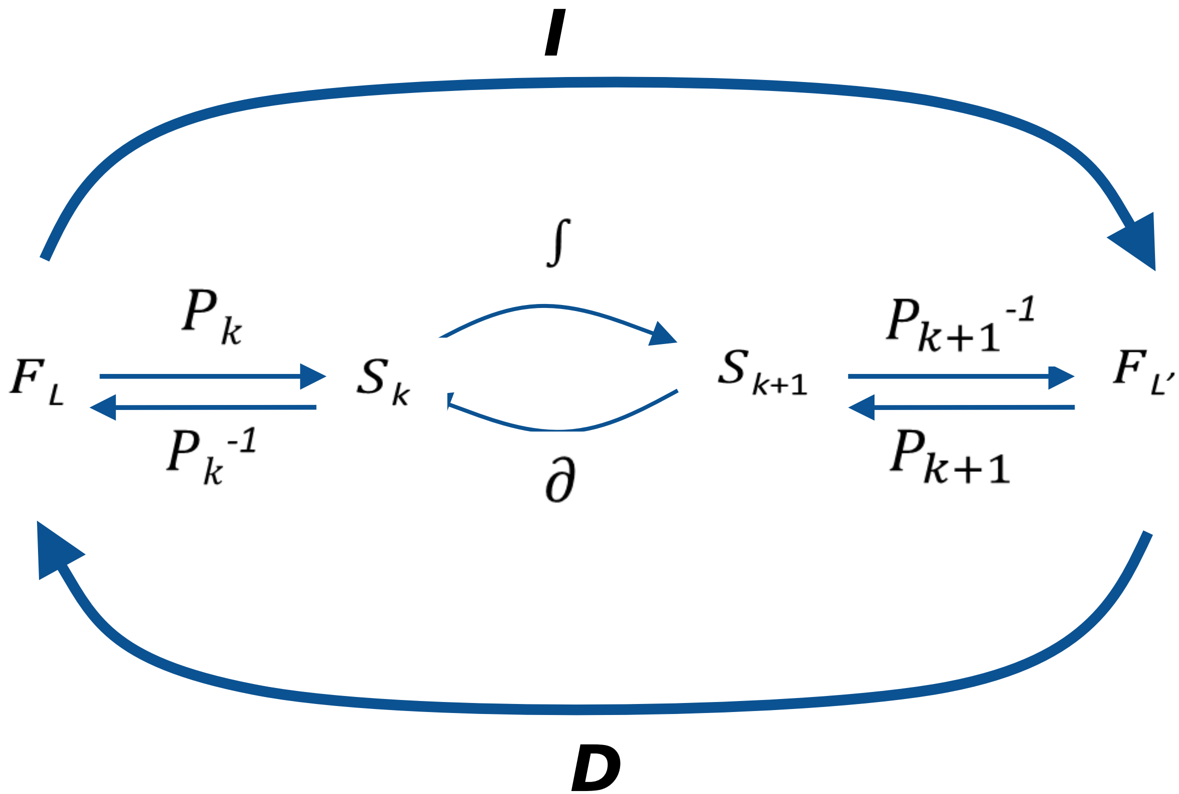
  Integral $\boldsymbol{I} : d \rightarrow w$ after SP calculations

- To keep the steady state $\frac{\partial w}{\partial t} = 0$ we need **invertibility** $\boldsymbol{I}.\boldsymbol{D}\, f = \boldsymbol{D}.\boldsymbol{I}\, f = f$
- Looking for operators on the space of B-splines of order *k* was unsuccessful

  $\Rightarrow$ FD version of $\boldsymbol{I},\boldsymbol{D}$ was kept with only first order of accuracy limiting the accuracy of the whole FE scheme

1. VFE in NH (J.Vivoda, A.Subias, J.Simarro)

We do not have to restrict ourselves on the space of *B*-splines of order *k* !



1. VFE in NH (J.Vivoda, A.Subias, J.Simarro)

Accuracy of derivative and integral operators:

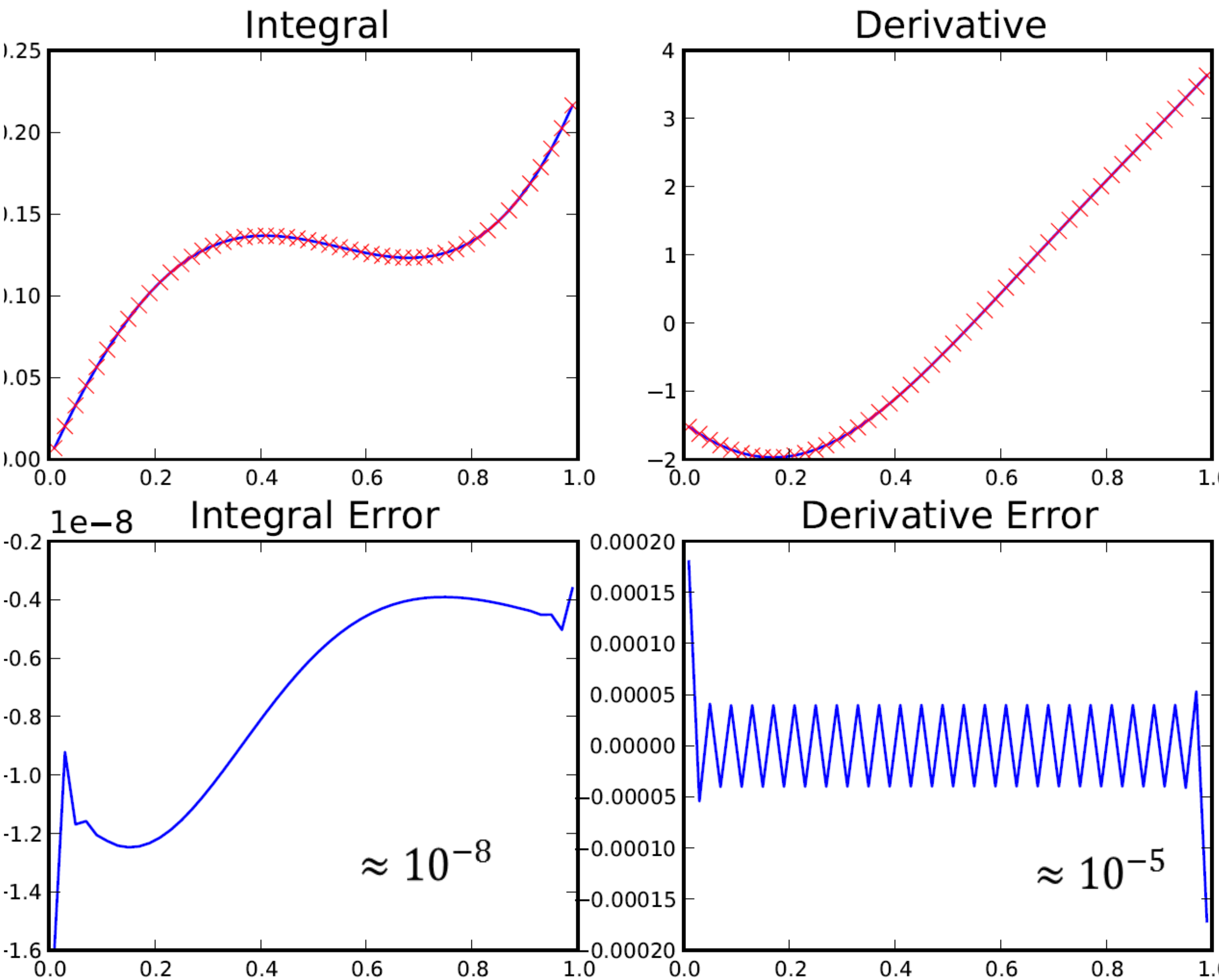
cubic B-splines

50 full levels

Test function of the type

$$F(z) = \frac{p_5(z)}{p_4(z)}\, e^z$$

Difference between analytical and numerical value →



1. VFE in NH (J.Vivoda, A.Subias, J.Simarro)

Accuracy of derivative and integral operators:

$$(I.D)^{300}.f = f \ ?$$

$$(D.I)^{300}.f = f \ ?$$

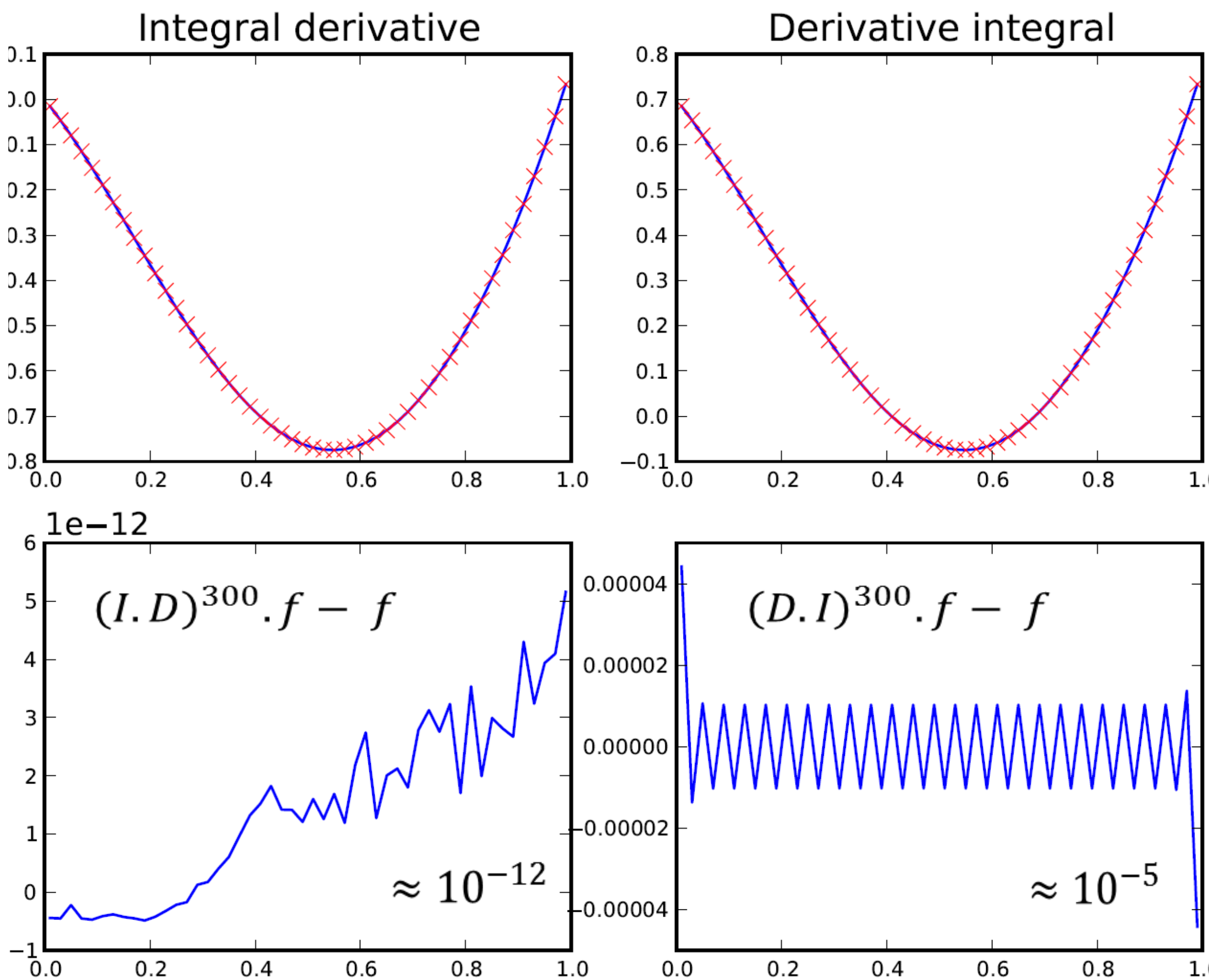
Not exactly

$$I.D.f = f - E.f$$

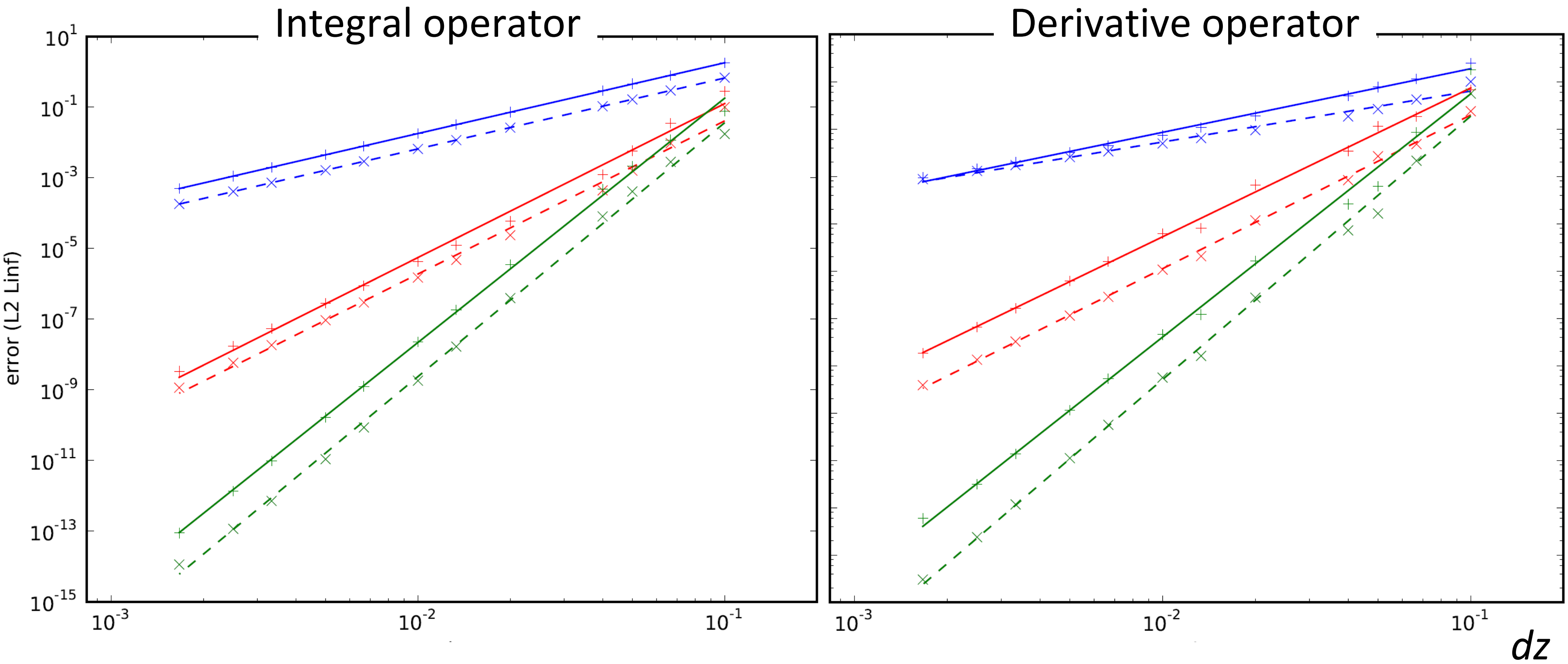
$$D.I.f = f - I^{-1}E.I.f$$

E gives an extrapolated value at *z=0*

z=0



1. VFE in NH (J.Vivoda, A.Subias, J.Simarro)



Convergence of vert. operators: integrals more accurate then derivatives

linear: $D \sim 1.3$, $I \sim 2$, cubic: $D \sim 3.1$, $I \sim 4.3$, quintic: $D \sim 5.1$, $I \sim 6.9$

2. Physical tendency of w (David Lancz)

- new topic in ALARO
- first step: the impact of **vertical turbulence** on the prognostic variable for vertical motion (either vertical divergence *d* or vertical velocity *w*)
- proposal of **Luc Gerard** considered
- use of turbulent diffusion flux estimated during the computation of the turbulent kinetic energy in TOUCANS parameterization (**Ivan Bašťák-Duráň**)

$$F_w = -\rho e \frac{2}{3}\left[1 - \frac{0.2}{1 - Ri_f}\right]$$

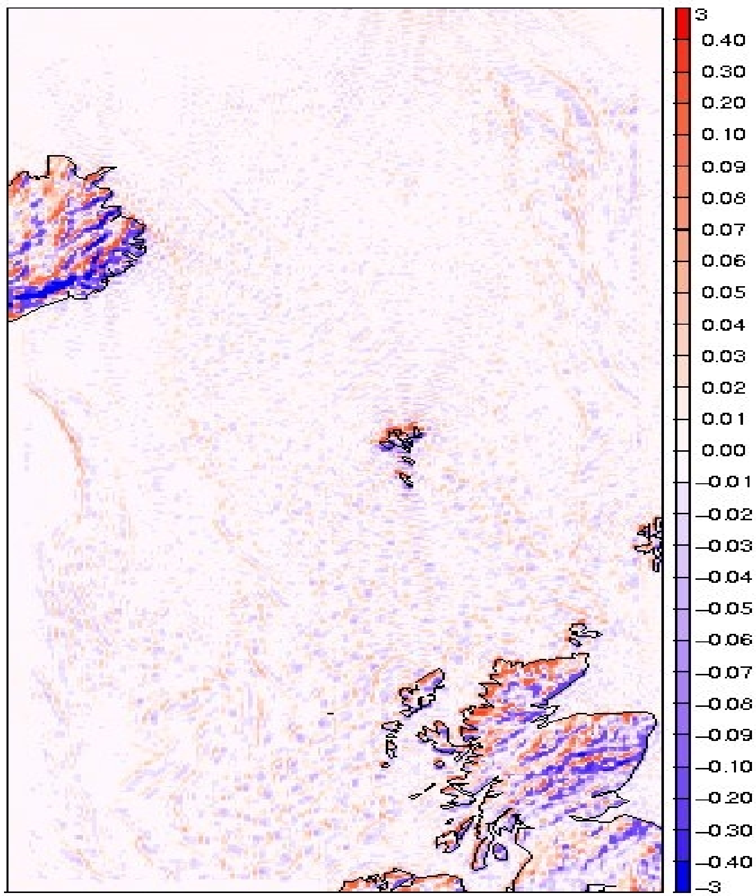
Question:

How big is the influence of vert. turbulence on w?

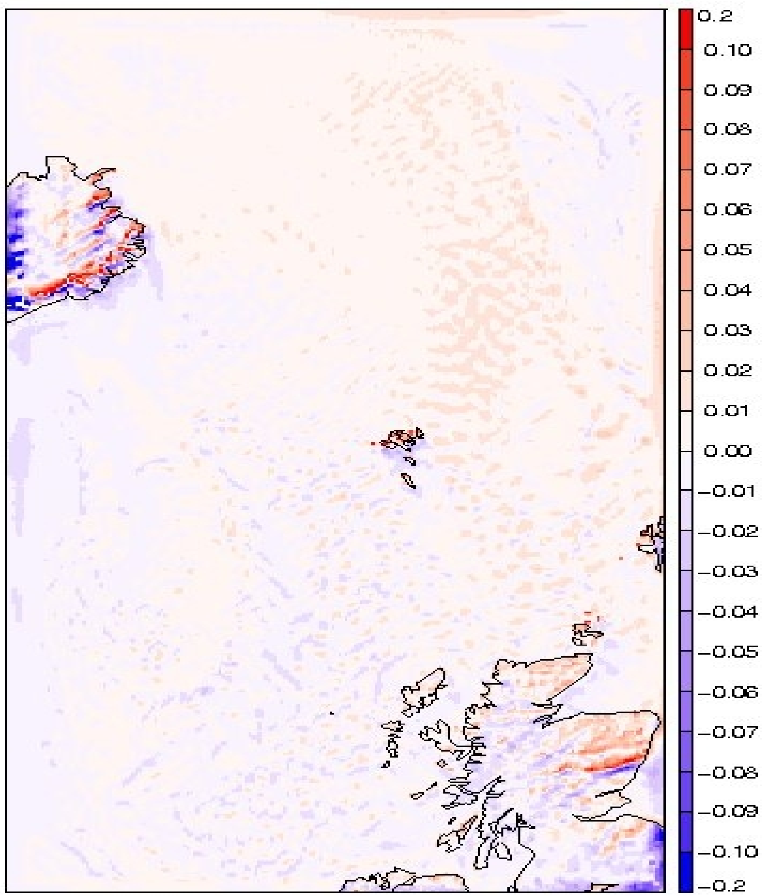
- 2 real case simulations (cold air outbreak over the North See and a convective situation over Central Europe with Alps)
- the change in vertical motion variable was detected **around 10%**
- turbulent component of *w* is smooth in time without oscillations and without causing instabilities

2. Physical tendency of w (David Lancz)

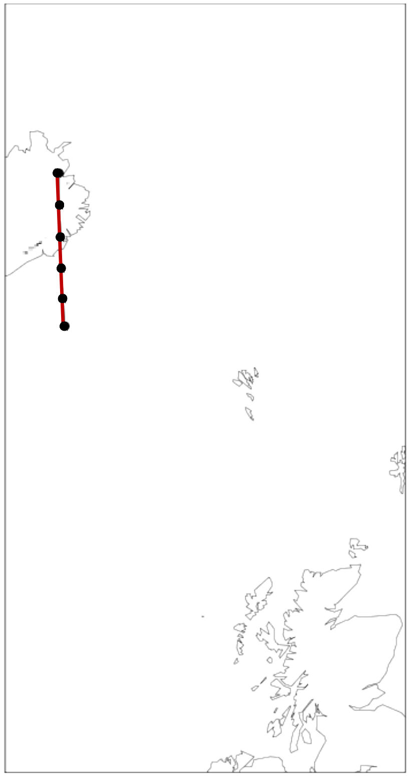
Vertical velocity, level 85 from 87



Tendency of w from vert.turbulence

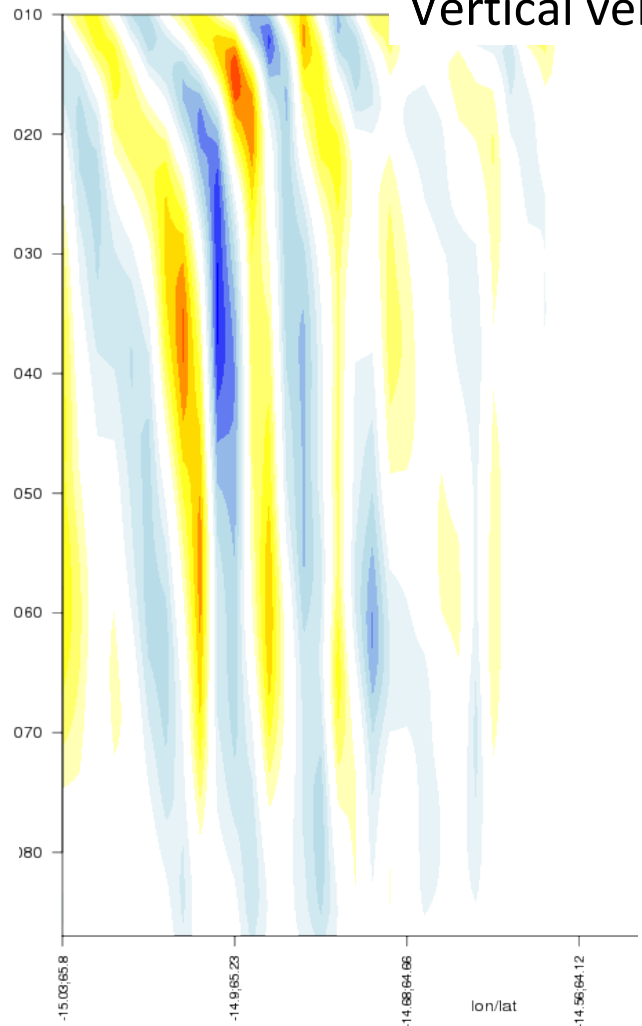


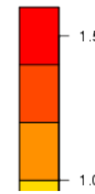
2. Physical tendency of w (David Lancz)



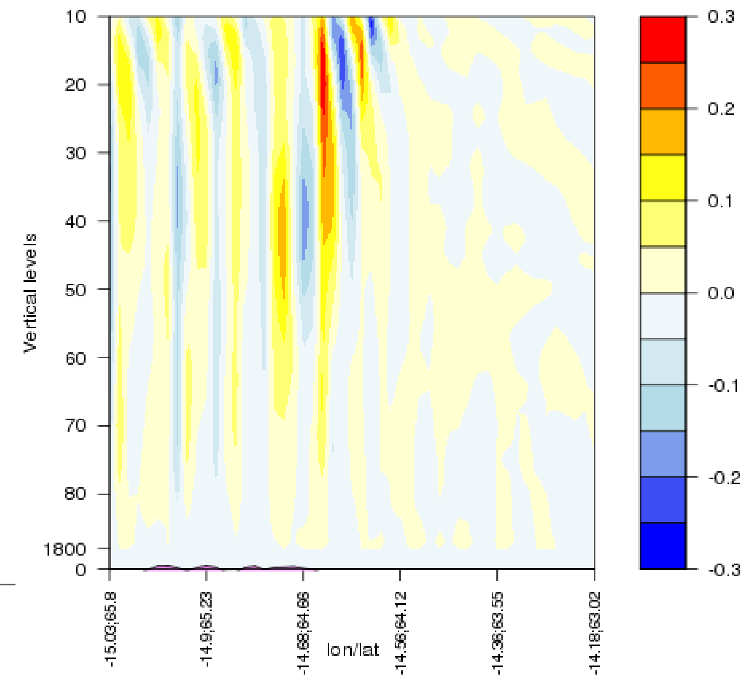
Vertical cross section

Vertical velocity



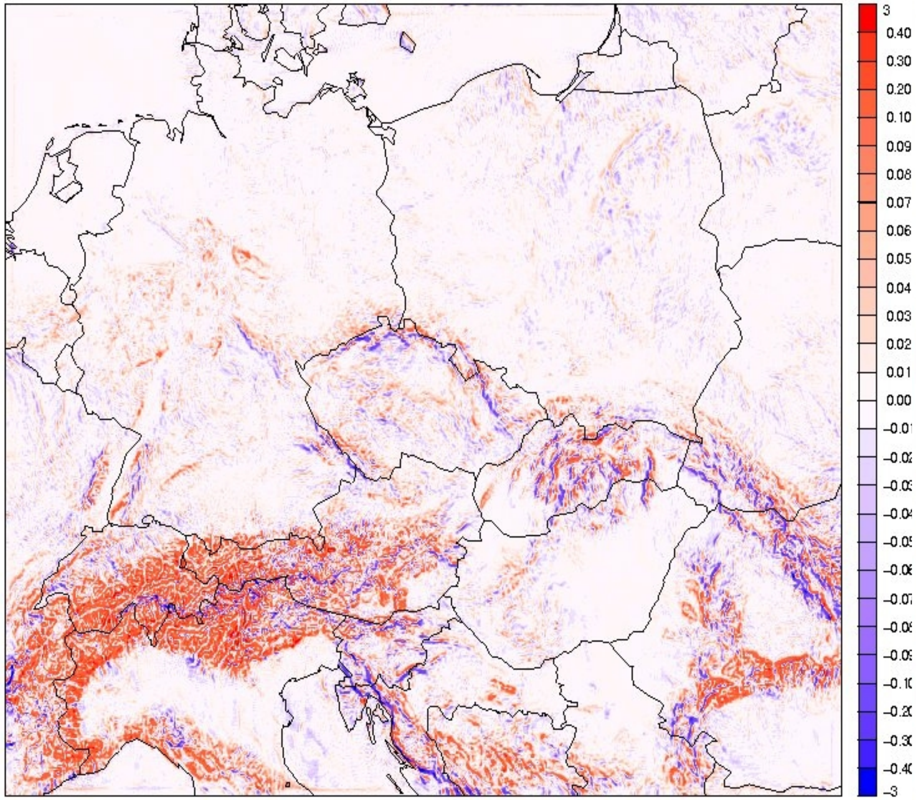


Difference – without and with turbulent flux

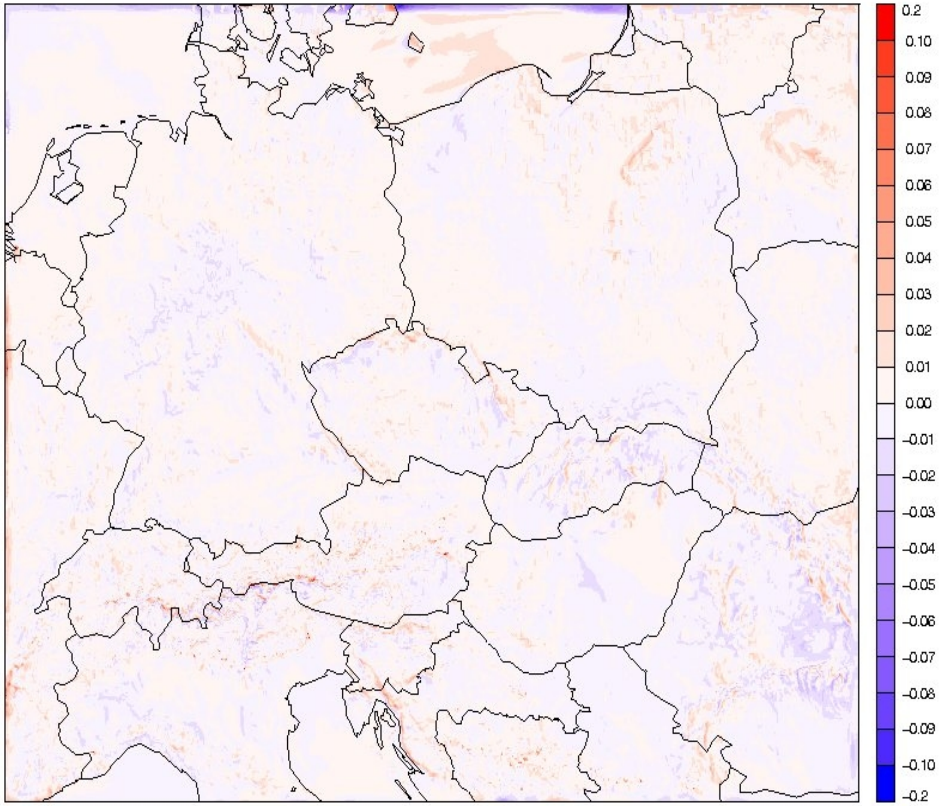


2. Physical tendency of w (David Lancz)

Vertical velocity, level 85 from 87



Tendency of w from vert.turbulence



Convective situation over Central Europe, 2.2 km horizontal resolution

3. SLHD tuning in ALARO 1km

Semi-Lagrangian horizontal diffusion
(implemented to ALADIN by Filip Váňa)

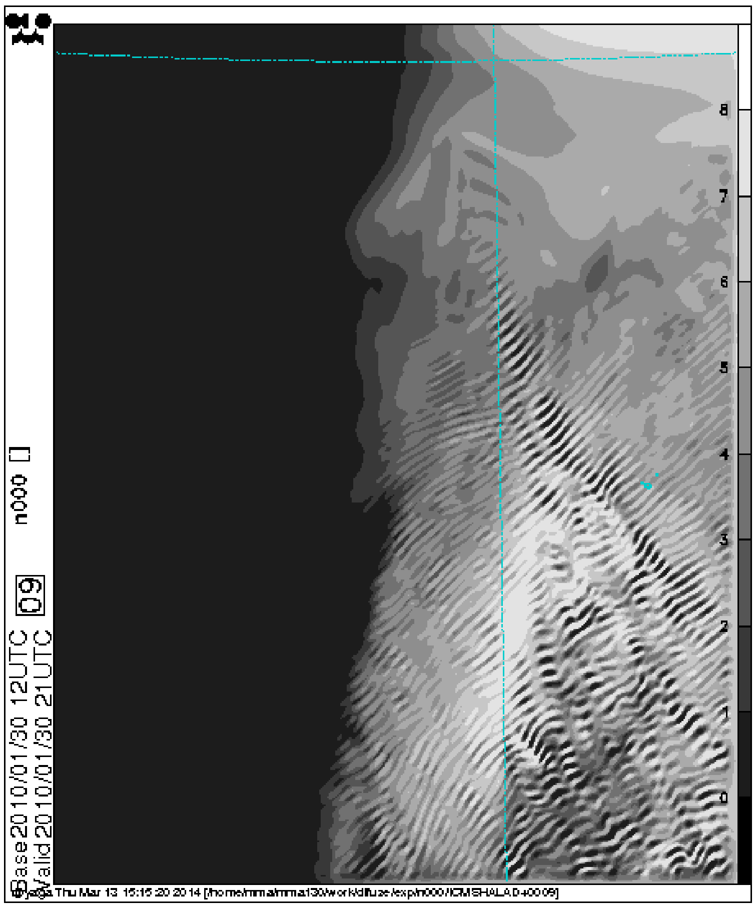
For the following purposes:

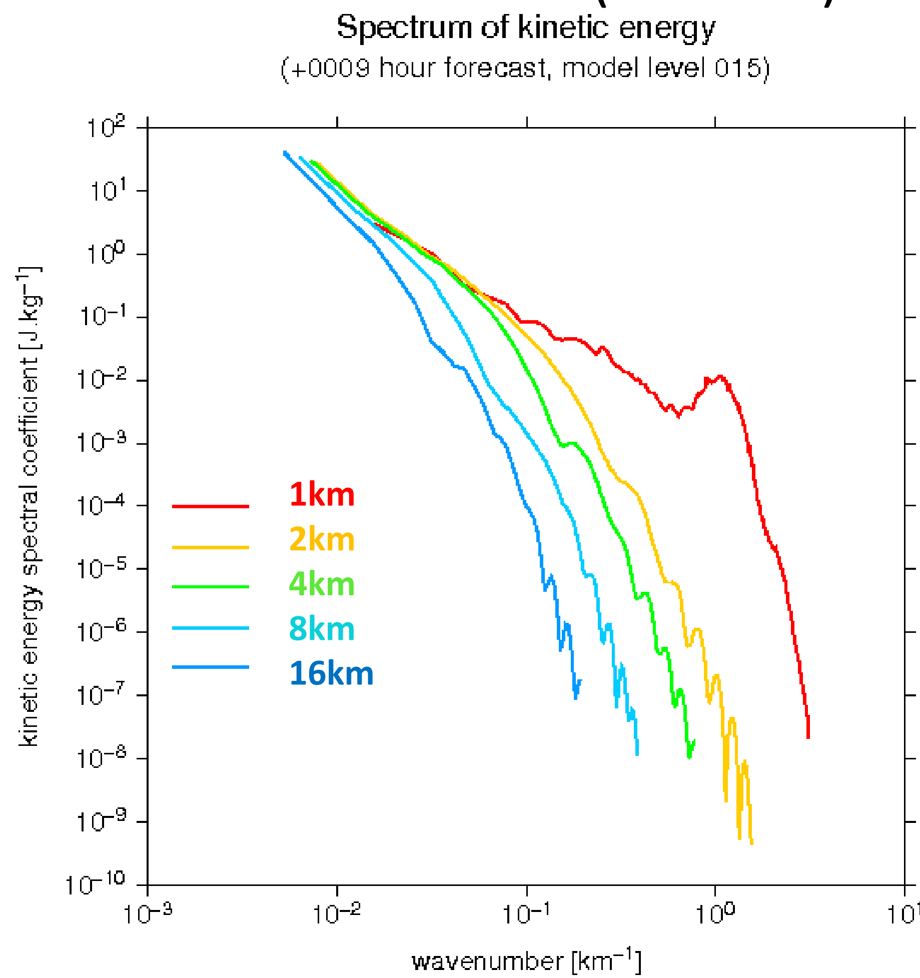
1) To represent the subgrid horizontal effect of **turbulence** and molecular dissipation
2) To **damp** the waves without predictive skills (to improve model scores)
3) To avoid the accumulation of energy at the end of the **model spectrum** (to keep the kinetic energy spectrum close to the one derived theoretically)

The diffusion coefficient is a function of **deformation** with several tunable parameters.

3. SLHD tuning in ALARO 1km

Grey zone experiment in the cascade of resolutions (Radmila)





3. SLHD tuning in ALARO 1km

Gridpoint part of SLHD

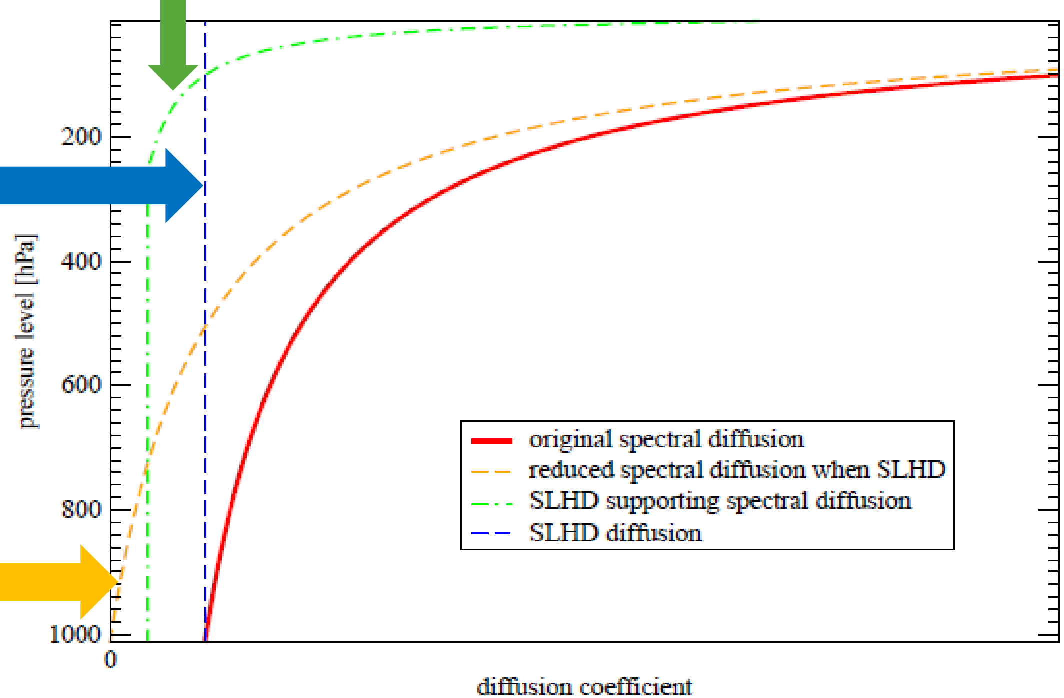
LSLHD_X = .T.
SLHDA0 = 0.25
SLHDB = 4.
SLHDD00 = 6.5E-05
ZSLHDP1 = 1.7
ZSLHDP3 = 0.6
adaptation on resolution
YX_NL%LSLHD = .T.
SLHDEPSH = 0.016
SLHDEPSV = 0.016
SLHDKMAX = 6.
SLHDKMIN = -0.6

Reduced spectral diffusion - enhanced damping with height

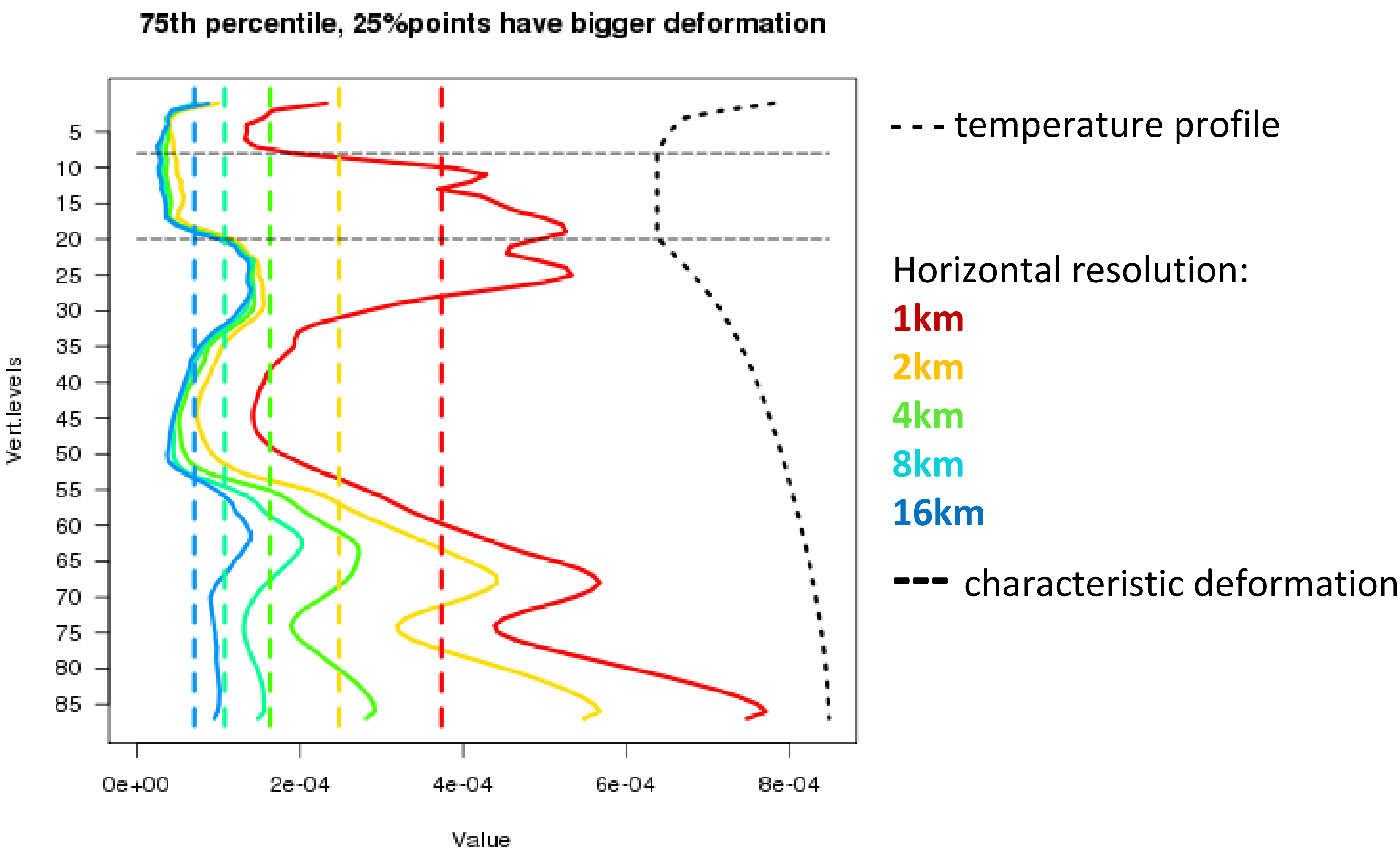
RRDXTAU=123.
REXPDH = 2.
SDRED = 1.
RDAMPX = 0.,…,1. for X=T,Q,VOR,DIV,VD,PD
SLEVDH = 0.1

Supporting spectral diffusion – to control impact of orography

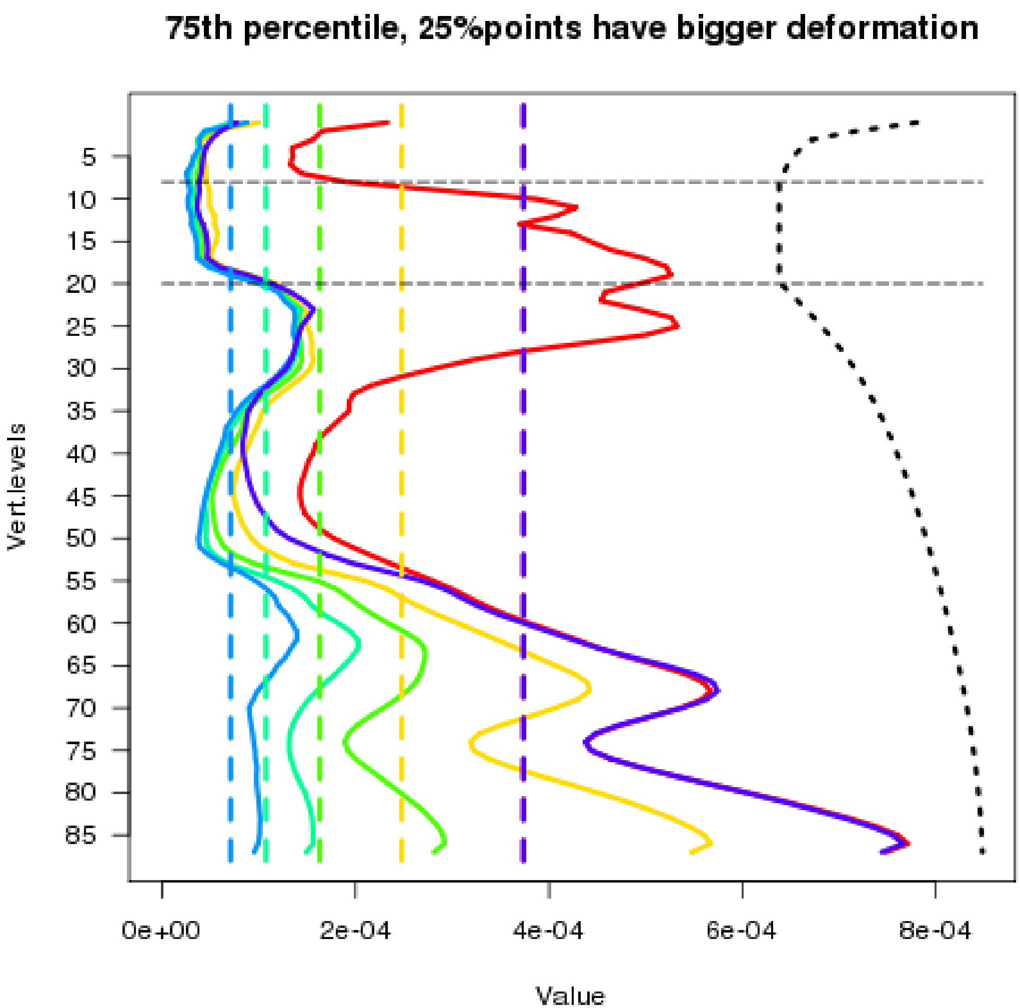
REXPDHS = 6.
RDAMPXS = 10.
SLEVDHS = 1.



3. SLHD tuning in ALARO 1km



3. SLHD tuning in ALARO 1km



- - - temperature profile

Horizontal resolution:

1km tuned

1km

2km

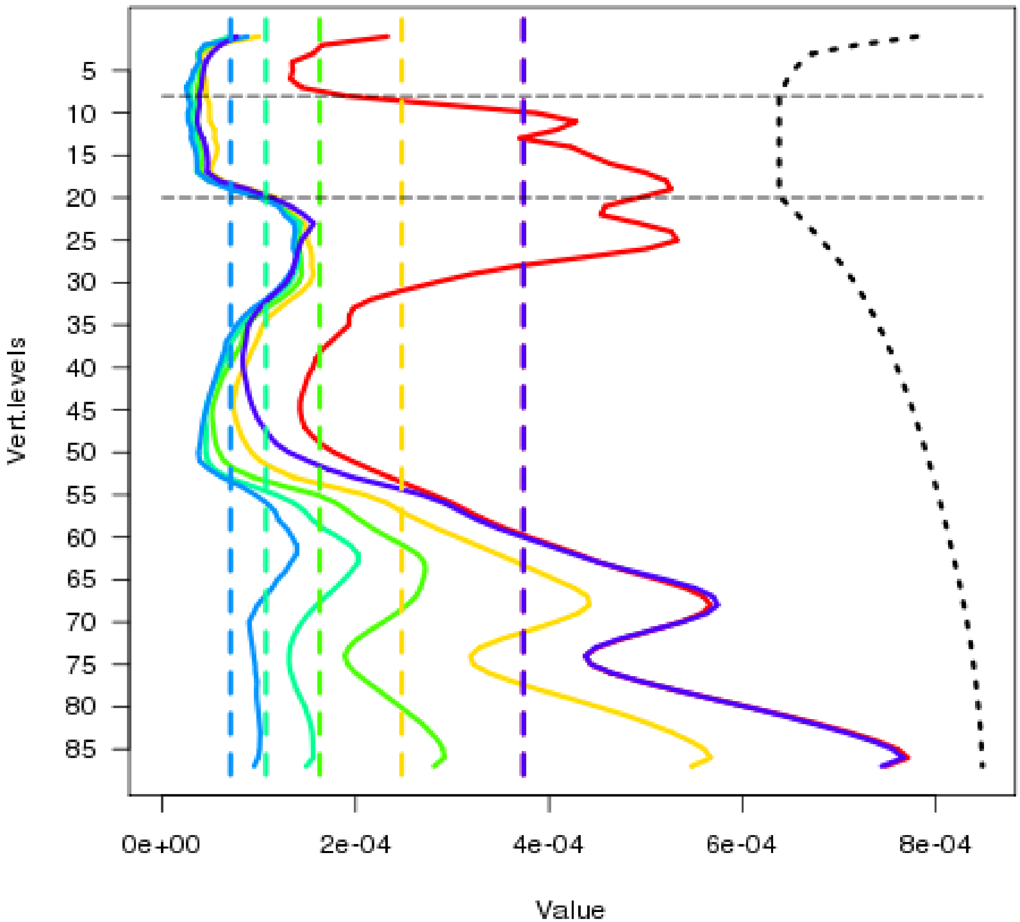
4km

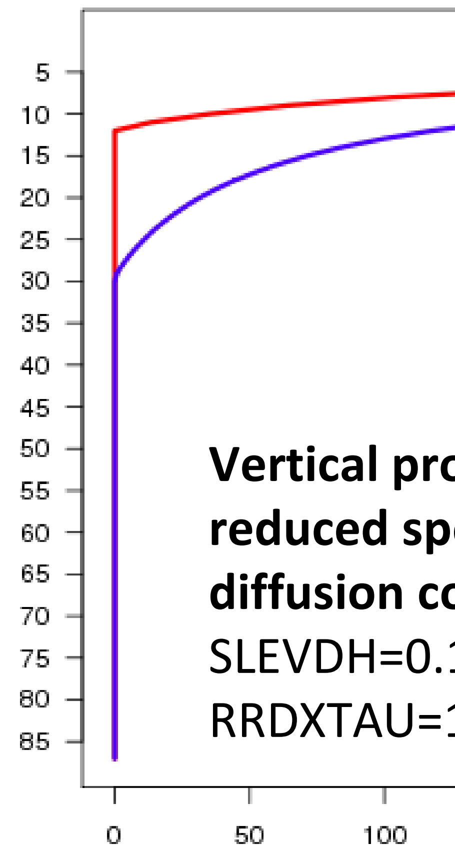
8km

16km

--- characteristic deformation

3. SLHD tuning in ALARO 1km



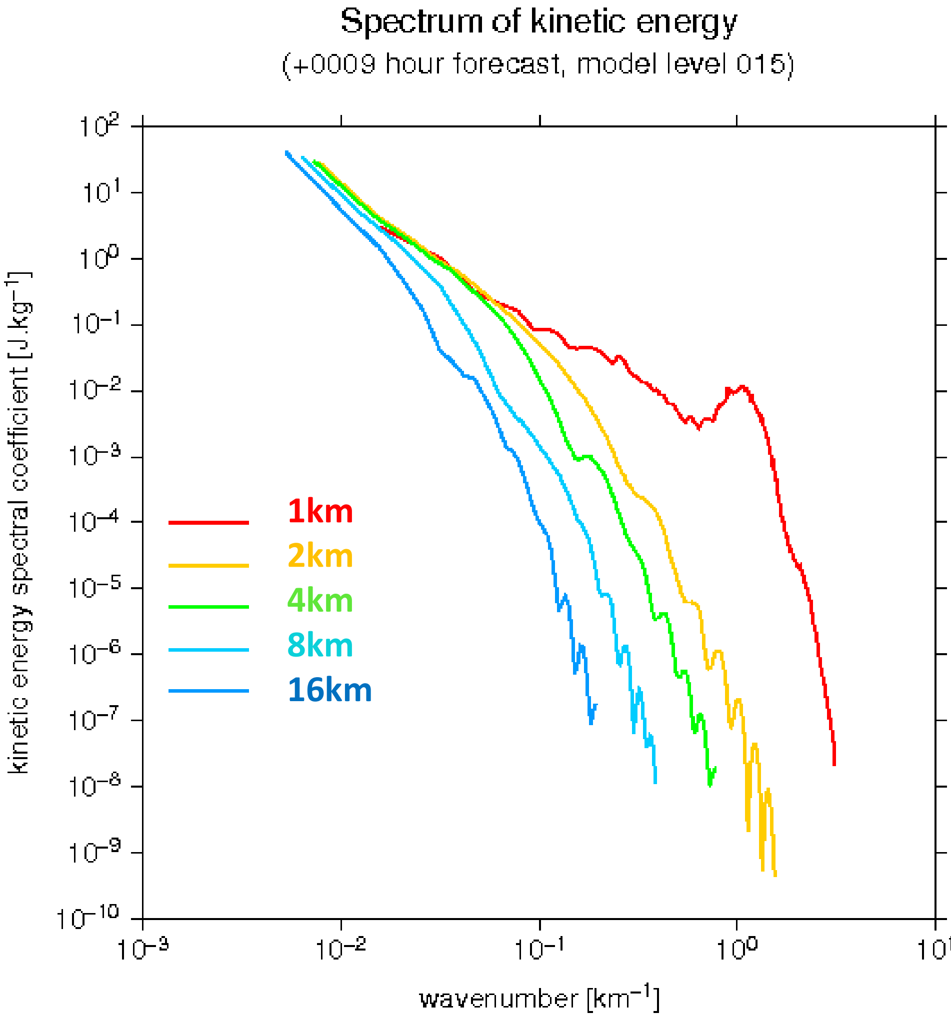


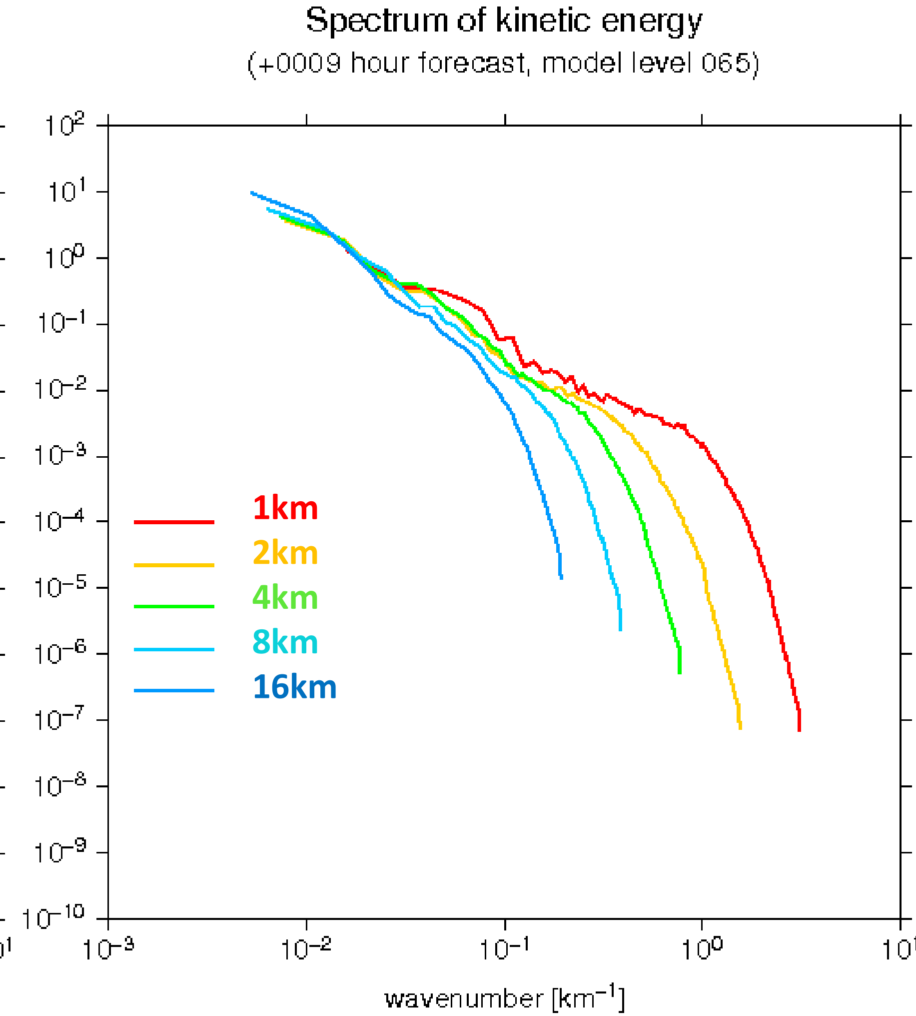
Vertical profile of reduced spectral diffusion coefficient:

SLEVDH=0.1 -> 0.4

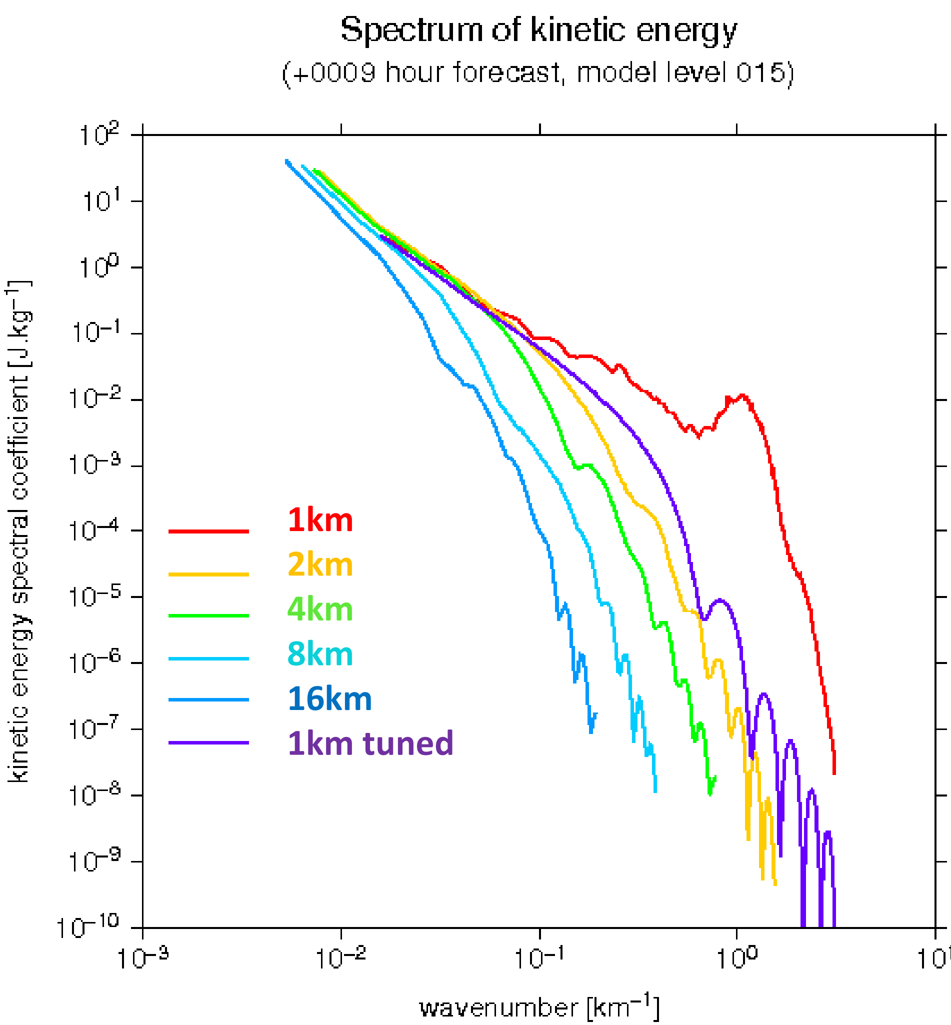
RRDXTAU=123. -> 31.

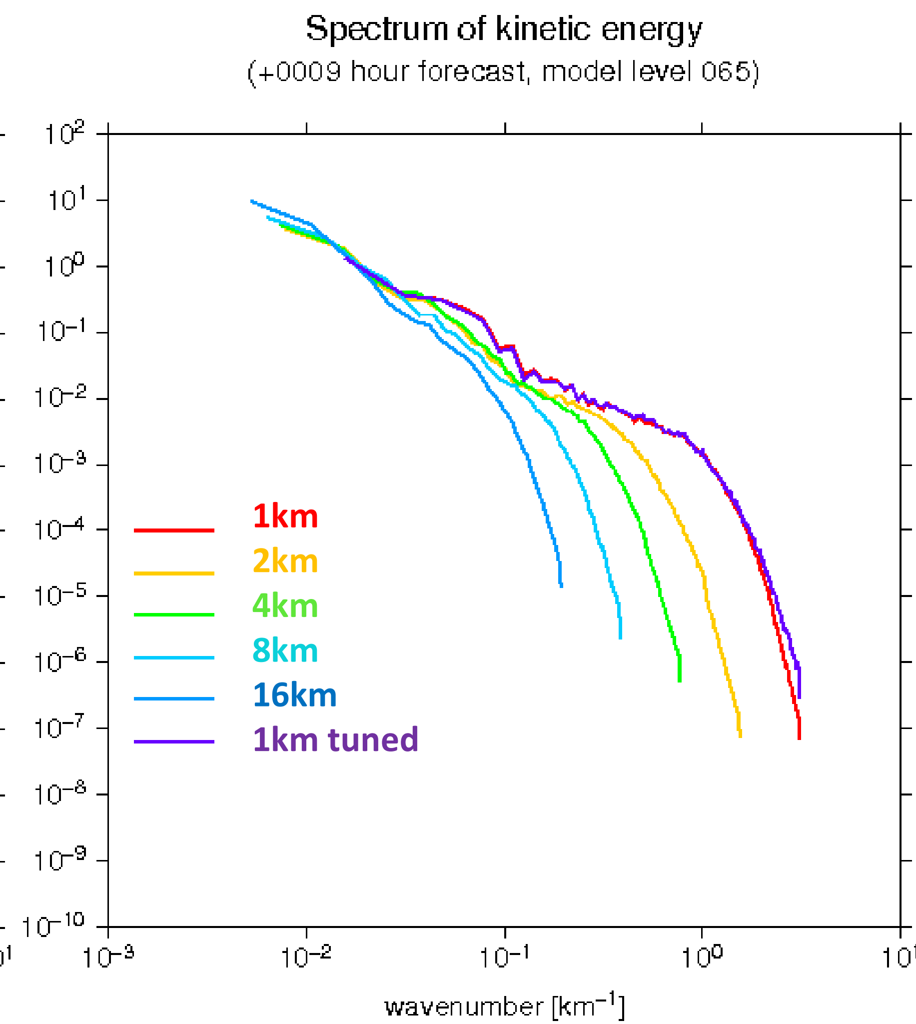
3. SLHD tuning in ALARO 1km



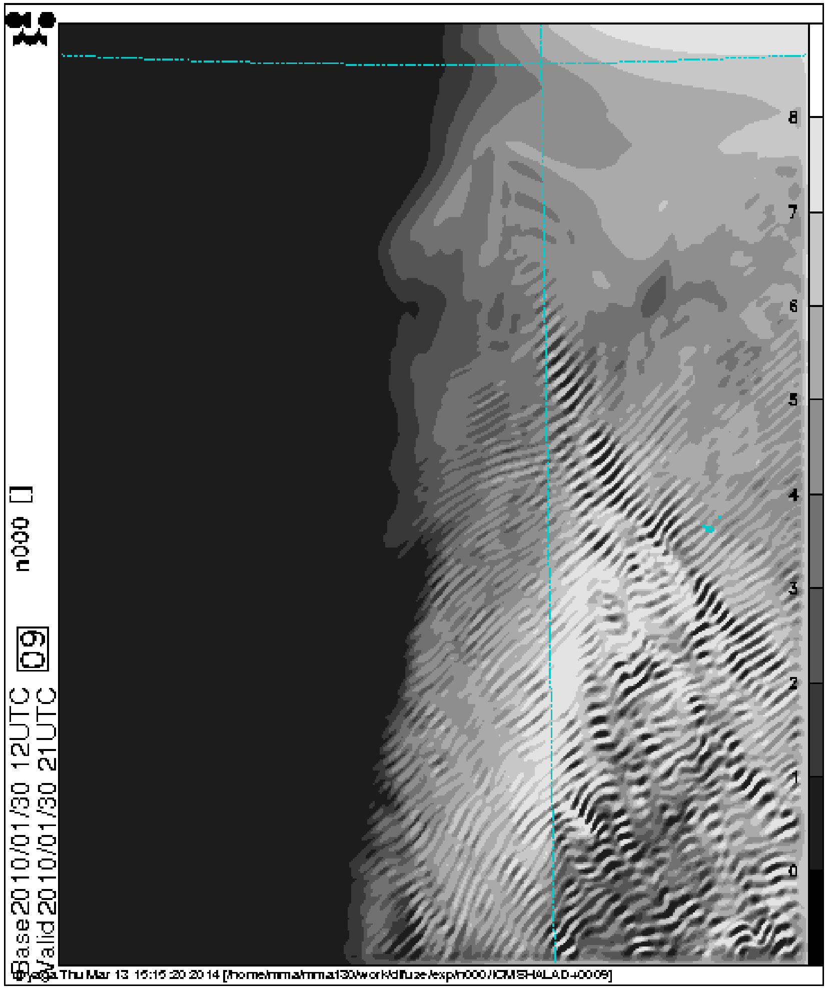


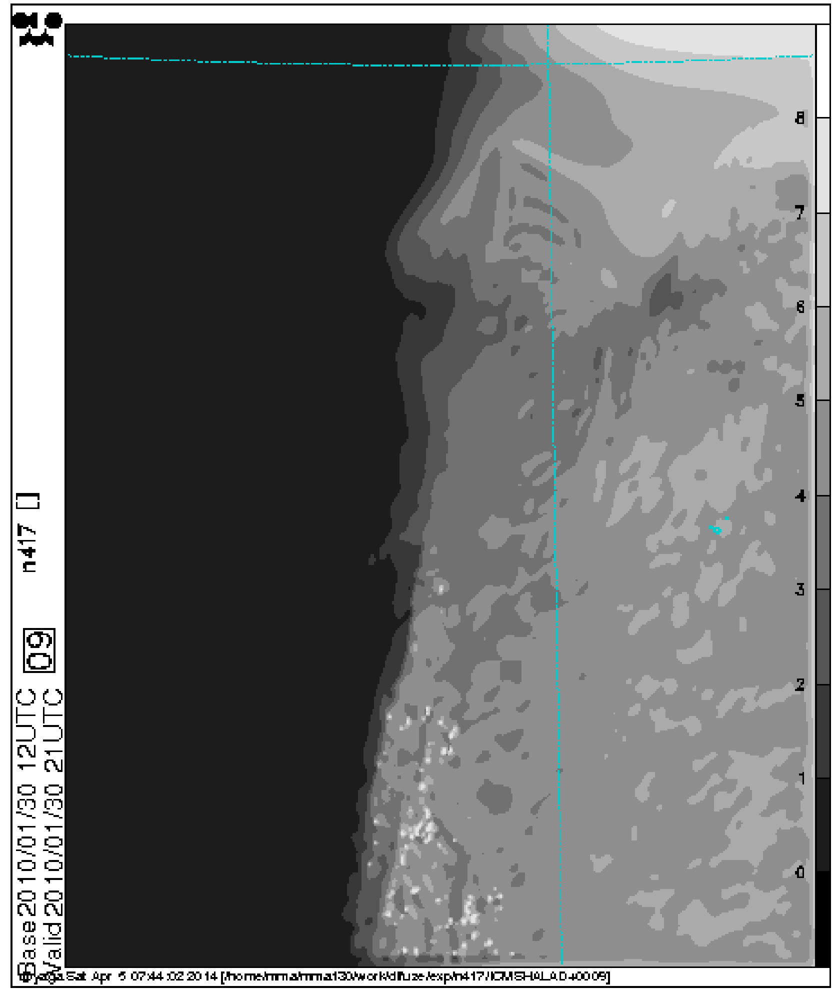
3. SLHD tuning in ALARO 1km





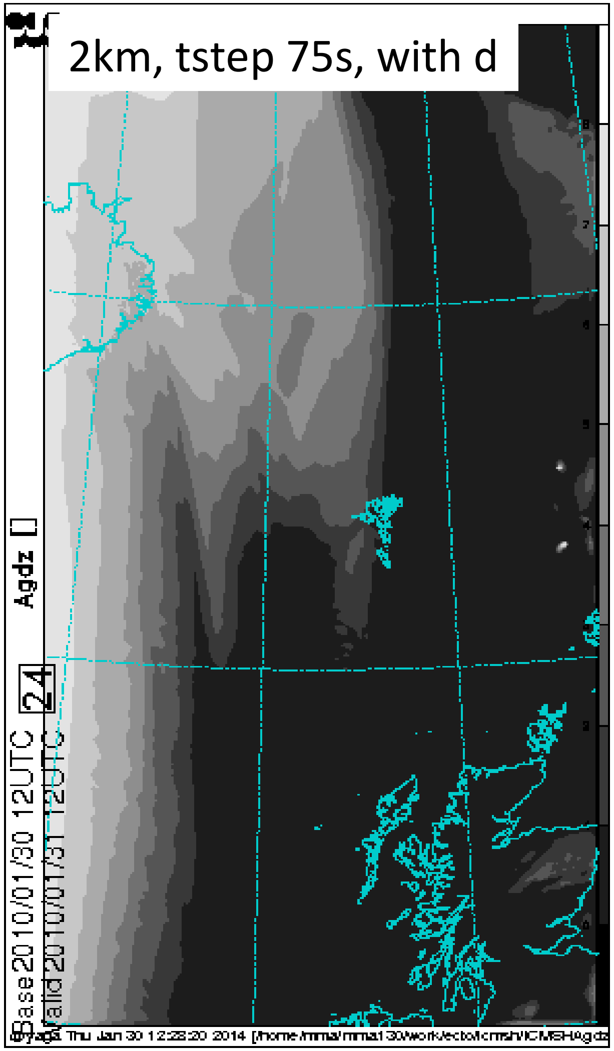
3. SLHD tuning in ALARO 1km





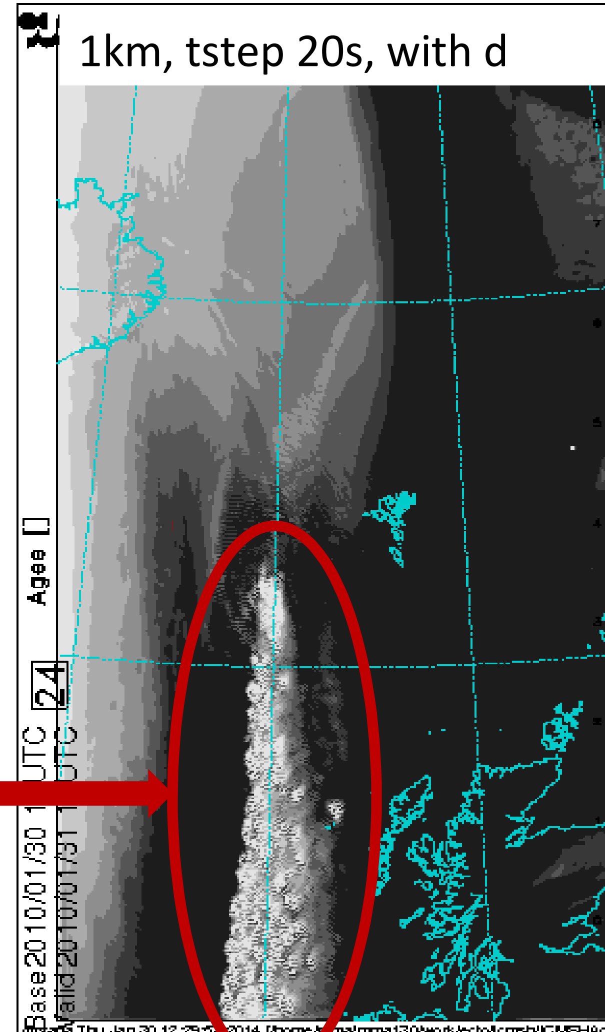
High level cloudiness: reference **tuned with SLEVDH=0.4,RRDXTAU=0.31**

3. SLHD tuning in ALARO 1km (R.Brožková)



LGWADV = FALSE

LGWADV = TRUE
1km, tstep 30s, with w
artificial cloud disappears



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PLANS

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Plans

1. VFE NH

- **thorough testing** of the VFE implementation in the cycle CY40T1
- to study the influence of **the B-spline order** on the accuracy and the time stepping stability of the whole system
- **to eliminate remaining FD features** (the top and bottom boundary conditions of the vertical Laplacian operator, invertible operators for derivation and integral being used in w,d transformations)
- **to show the benefits** of the proposed method in comparison with the FD method (enhanced theoretical accuracy of vert. operators used, comparison of analytical and numerical normal modes)

Plans

2. Physics-dynamics interface

- to add the convective part of **physical tendency of w** to NH
- to study high order ENO (Essentially Non-Oscillatory) **interpolations in SL** scheme – Alexandra Craciun (Ro)
- to define a share between the physical diffusion (SLHD) and the numerical diffusion (spectral dif.) in convective situations being independent from scale

14th EMS Annual Meeting & 10th European Conference on Applied Climatology (ECAC)

http://www.ems2014.eu 06 – 10 October 2014, Prague, Czech Republic

Conference Theme: **Creating climate services through partnerships**

Program Groups:

- European Conference on Applied Climatology (ECAC)
- Communication and Education
- The Atmospheric System and its Interactions
- **Numerical Weather Prediction**
  - **NWP1 - Dynamics and predictability of high impact weather in operational forecasting, including nowcasting**
  - **NWP2 - Numerical aspects and physical parameterization**
  - **NWP3 - Data assimilation and use of observations in meteorology and oceanography**
  - **NWP4 - Probabilistic and ensemble forecasting at short and medium-range**
  - **NWP5/ASI14 - Mountain Meteorology (co-organized)**

Deadline for abstract submission: **15 April 2014**

Thank you for your attention!