Regional Cooperation for Limited Area Modeling in Central Europe

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ACCORD
A Consortium for COnvection-scale modelling Research and Development

Setting dynamics options in VHR

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Basic choices

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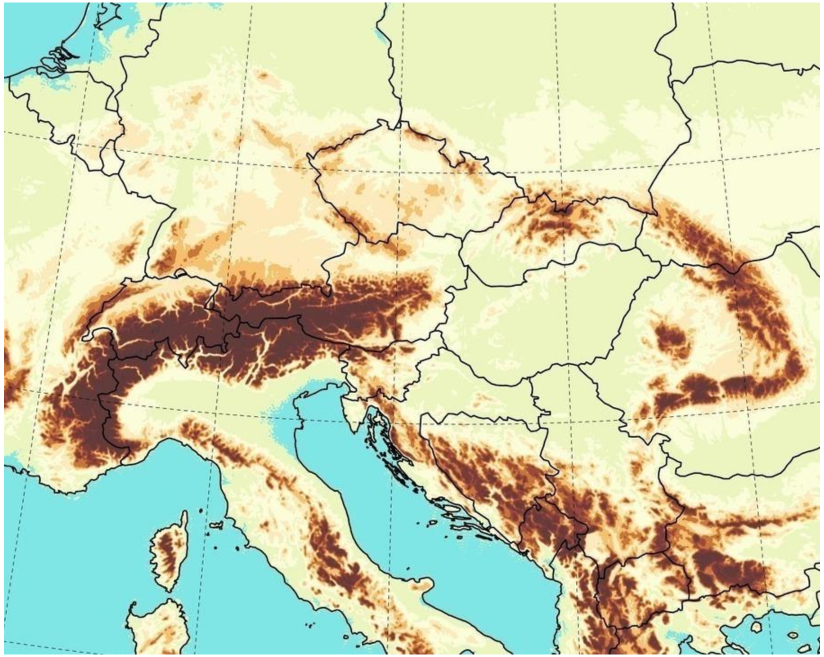
Set already during the preparation of clim files or PGD:

- Points in x: NDLON -> NDLUX=NDLON-11 (without extension zone)
  Points in y: NDGL -> NDGUX=NDGL-11
- Truncation in x: NMSMAX
  in y: NSMAX
- Coupling zone half-width in x: NBZONL
  in y: NBZONG
- Horizontal resolution in x: EDELX
  in y: EDELY
- Central point: ELATC, ELONC
- Projection reference point: ELAT0, ELON0
- Vertical levels through As and Bs



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Time scheme

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- Semi-implicit or iterative centered implicit scheme

$$\frac{R_F^{+(0)} - R^0_{O(0)}}{\Delta t} = \mathcal{L}\left(\frac{R_F^{+(0)} + R^0_{O(0)}}{2}\right) + (\mathcal{M} - \mathcal{L})\left(R_M^{m(0)}\right)$$

$$\frac{R_F^{+(n)} - R^0_{O(n)}}{\Delta t} = \mathcal{L}\left(\frac{R_F^{+(n)} + R^0_{O(n)}}{2}\right) + (\mathcal{M} - \mathcal{L})\left(R_M^{m(n)}\right)$$

- How many times the Helmholtz equation is being solved? n times

$$\left(1 - \frac{\Delta t}{2}\mathcal{L}\right) R_F^{+(n)} = \left(1 + \frac{\Delta t}{2}\mathcal{L}\right) R^0_{O(n)} + (\mathcal{M} - \mathcal{L})\left(R_M^{m(n)}\right)$$

NSITER=0,1,2,3

corresponds to last n

LPC_FULL=T for NSITER>0

LPC_CHEAP=T for

$$O^{(n)} = O^{(0)}$$

Time scheme

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- How $R_M^{m(0)}, R_M^{(n)}$ is calculated?
- Extrapolating scheme SETTLS or non-extrapolating scheme NESC may be applied:

$$R_M^{m(0)} = \frac{R_F^0 + R_O^0}{2}$$

$$R_M^{m(0)} = \frac{R_F^0 + 2R_O^0 - R_O^-}{2}$$

$$R_M^{m(n)} = \frac{R_F^{+(n-1)} + R_O^0}{2}$$

- Similar choice is done for the calculation of the semi-Lagrangian trajectory:
  - in horizontal
  - in vertical
  - trajectory search is also iterative with NITMP iterations, one iteration ~1%CPU

LSETTLS=T & LNESC=F

or

LSETTLS=F & LNESC=T

LSETTSLT=T & LNESCT=F

LSETTLSV=T & LNESCV=F

or the opposite

NITMP = 3, 4, 5, …

Time scheme decentering

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- First order decentering: VESL

$$\frac{R_F^{+(n)} - R^0_{O(n)}}{\Delta t} = \mathcal{L}\left(\frac{(1+\epsilon)R_F^{+(n)} + (1-\epsilon)R^0_{O(n)}}{2}\right) + (\mathcal{M}-\mathcal{L})\left(\frac{(1+\epsilon)R_F^{+(n-1)} + (1-\epsilon)R^0_{O}}{2}\right)$$

- Pseudo-second order decentering: XIDT

  - for linear terms only

- Brings more stability, but less accuracy

VESL = 0.

XIDT = 0.

Time scheme

- Stability/efficiency trade-off:

  Time scheme price depends on the number of iterations of the time scheme,

  the chosen complexity of the time scheme and the chosen time step

- Iterative schemes (PC): NSITER iterations

  Helmholtz solver – iterated

  spectral transformations – iterated

  trajectory search – not iterated for LPC_CHEAP=T

  SL interpolations – not iterated for LPC_CHEAP=T

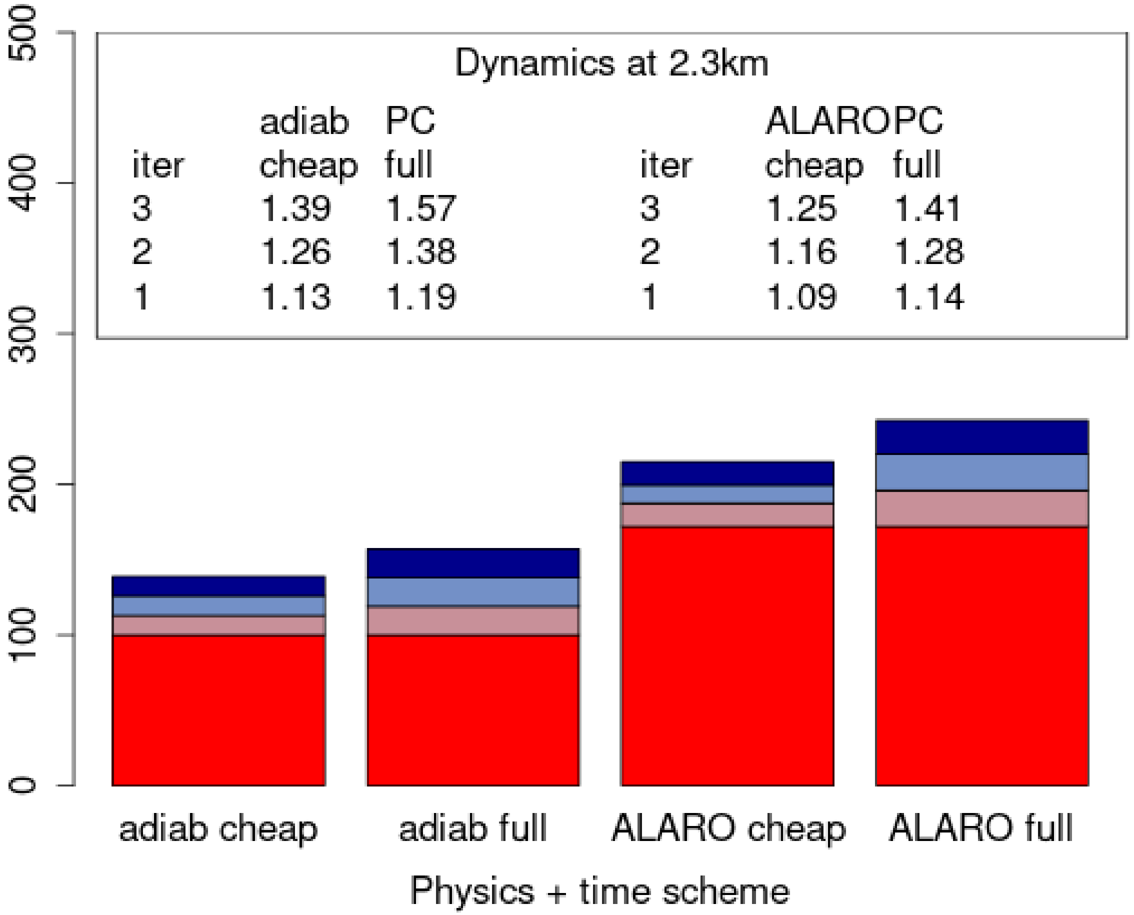
  horizontal diffusion – not iterated for LRHDI_LASTITERPC=T (default)

  physics – not iterated

Time scheme

- Stability/efficiency trade-off:

1 iteration of PC CHEAP needs only about 10% of additional CPU time when compared to ALARO run



Linear model definition

- Reference temperature:

  SITR = 350K
  SITRA ≤ 100K

Bénard: The 2TL scheme for the EE systém is stable if

$$SITRA < T < SITR$$

everywhere in the domain.

- Reference pressure:

  relatively high SIPR recommended

SITR = 350.

SITRA = 100. or less

SIPR = 90000.

Spectral diffusion

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$$\left(\frac{dX}{dt}\right)_{HD} = -\mathcal{K}_X M \nabla^r X$$

$$\mathcal{K}_X = \Omega_X \cdot g(l) \cdot f(n, N, \dots)$$

- Order r = REXPDH
- Strength

$$\Omega_X = \frac{RDXTAU}{RDAMPX}\left(1+\frac{i}{2}\right)^{2.5}[\Delta X]_{GP}$$

- Vertical profile

$$g(l) = min(SLEVDH\frac{\pi_{ref}}{\pi_{st}(l)}, \frac{1}{SLEVDH3}) - s_{dred}$$

with NPROFILEHD=1-3

in listing under PDILEV=...

REXPDH = 4.

RDAMPX = 1. (smaller->stronger)
RRDXTAU = 123. (bigger-> stronger)

SDRED = 0.
SLEVDH = 1.
SLEVDH3 = 100./VP00

NPROFILEHD = 3

Spectral diffusion

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$$\left(\frac{dX}{dt}\right)_{HD} = -\mathcal{K}_X M \nabla^r X$$

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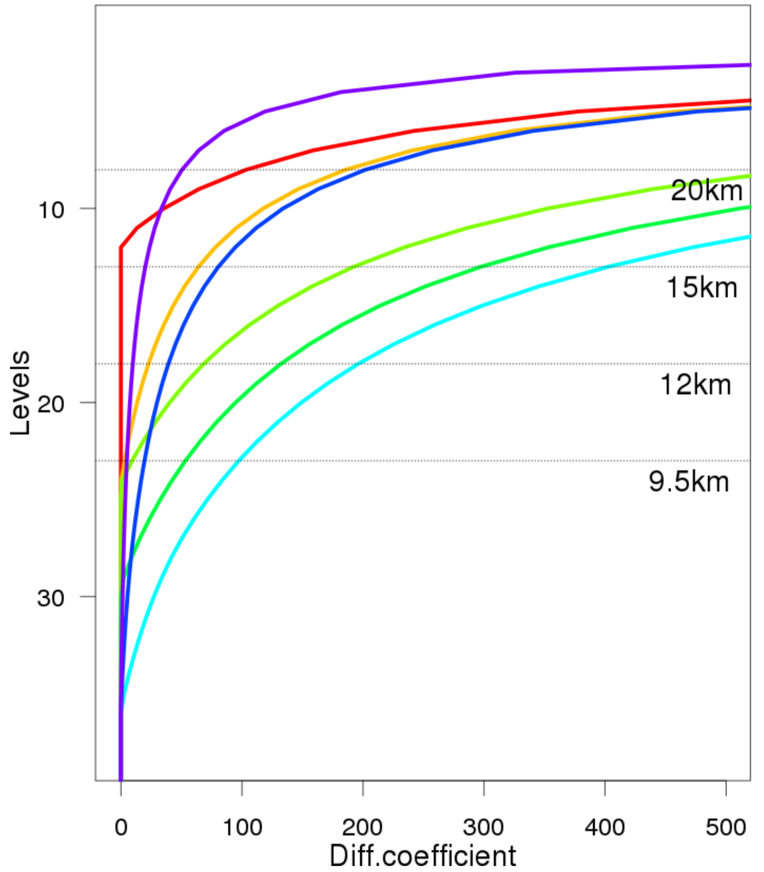
with NPROFILEHD=1-3

in listing under PDILEV=...



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SLHD

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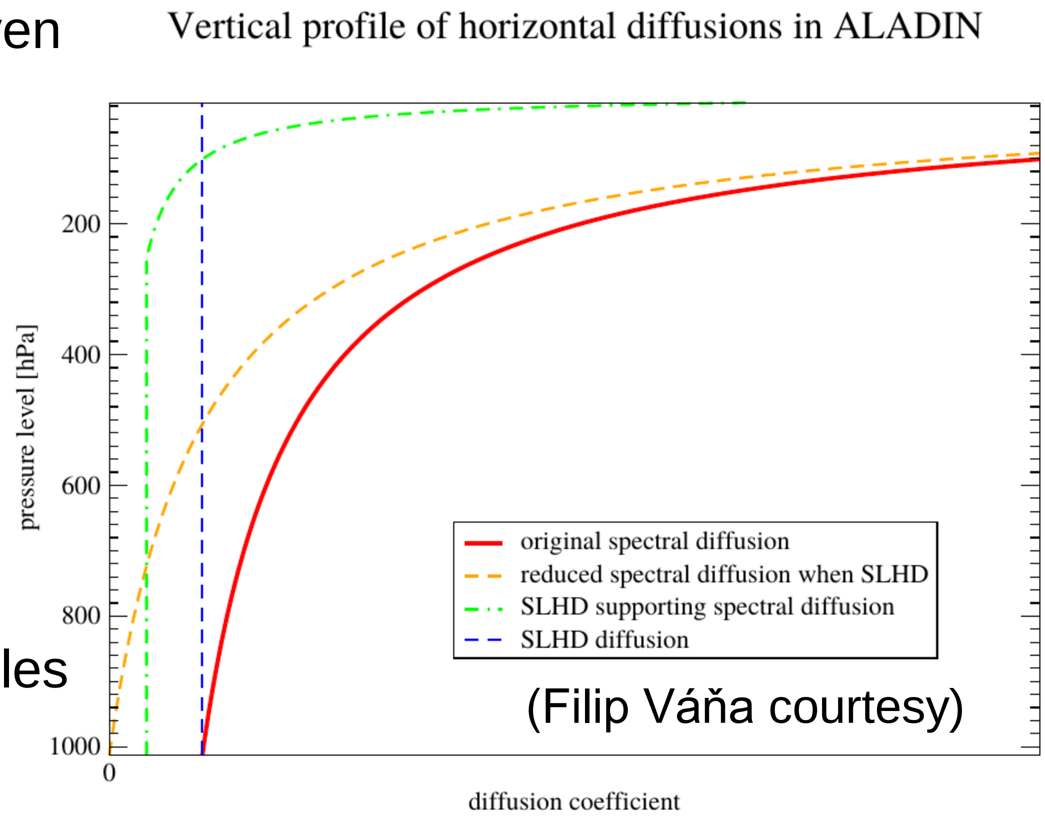
- Still spectral diffusion is needed, even two kinds:
  - reduced spectral diffusion
    - Order
    - Strength
    - Vertical profile
  - supporting spectral diffusion
    - Order
    - Strength
    - Vertical profile
- May be applied on grid point variables (GFL) as well



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SLHD

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- Still spectral diffusion is needed, even two kinds:
  - reduced spectral diffusion
    - Order
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    - Vertical
  - supporting spectral diffusion
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    - Strength
    - Vertical profile
- May be applied on grid point variables (GFL) as well

REXPDH=2.

RDAMPX=…

SLEVDH=0.5

SDRED=1.

In listing in PDILEV_SLHD

REXPDHS=6.

RDAMPXS=…

SLEVDHS = 1.

in listing in PDILEVS

SLHD

- Flow dependent diffusion coefficient kappa:

$$f(d) = a \cdot d \left(max \left[1, \frac{d}{d_0} \right] \right)^{SLHDB}$$

$$a = 2\ SLHDA0 \left(\frac{\Delta x_{ref}}{\Delta x} \right)^{ZSLHDP1}$$

$$d_0 = 0.5\ SLHDD00 \left(\frac{\Delta x_{ref}}{\Delta x} \right)^{ZSLHDP3}$$

$$\kappa = \frac{f(d)\Delta t}{1 + f(d)\Delta t}$$

- SL interpolations according to kappa

  => controlled diffusivity

SLHDA0 = 0.25

SLHDB = 4.

SLHDD00 = 0.000065

ZSLHDP1 = 1.7

ZSLHDP3 = 0.6

Vertical motion variable

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- Modified vertical divergence in linear part

$$d_4 = \underbrace{-g\frac{p}{mRT}\frac{\partial w}{\partial \eta}}_{d_3} + \underbrace{\frac{p}{mRT}\nabla\phi\frac{\partial V}{\partial \eta}}_{X}$$

- Modified vertical velocity in non-linear part

$$w = w_S + \frac{1}{g}\int_\eta^1 \frac{mRT}{p}(d_4 - X)$$

- X-term treatment

$$\frac{dd_4}{dt} = \frac{dd_3}{dt} + \frac{dX}{dt}$$

$$ND4SYS = 1: \quad \frac{dX}{dt} = \frac{X_M^m - X_O^0}{\frac{\Delta t}{2}} \quad \text{iterated}$$

$$ND4SYS = 2: \quad \frac{dX}{dt} = \frac{X_F^{+0} - X_F^0}{\Delta t} + \frac{X_F^0 - X_O^0}{\Delta t}$$

last corrector   iterated

NVDVAR = 4

LGWADV = T

ND4SYS = 2

Vertical motion variable

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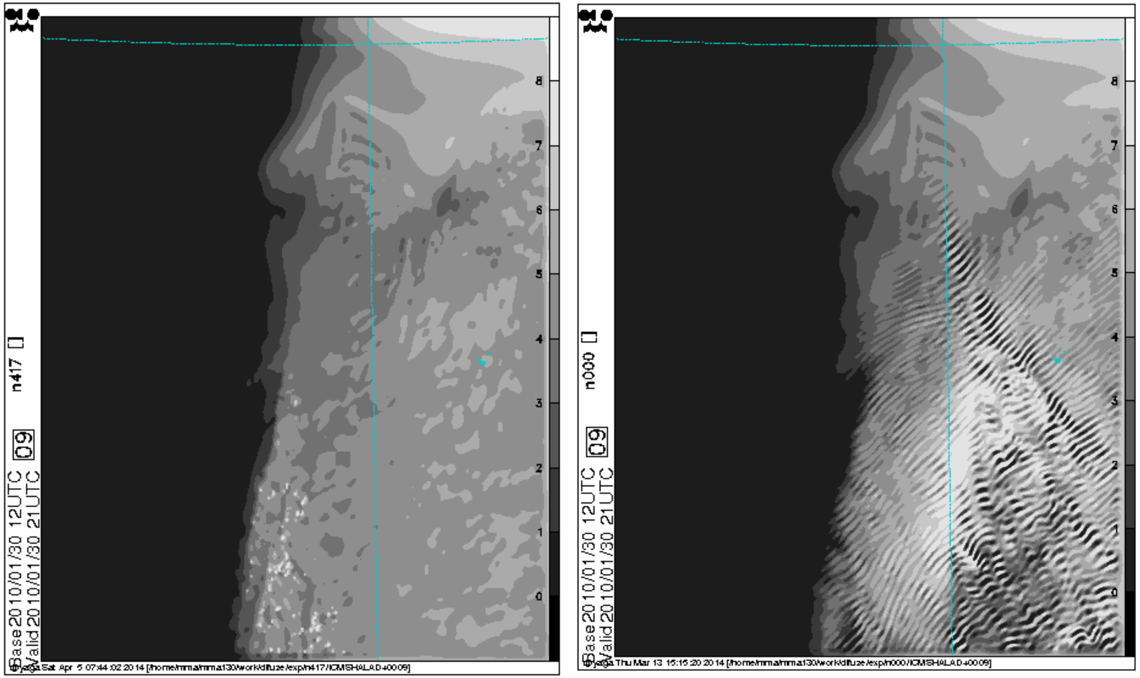
- Using only d3 (NVDVAR=3) is less stable and potentially dangerous
- Using only d variable (LGWADV = F) is dangerous, even with LRDBBC=T; this peace of code is not maintained

Cloudiness with d4 and d3



Vertical motion variable

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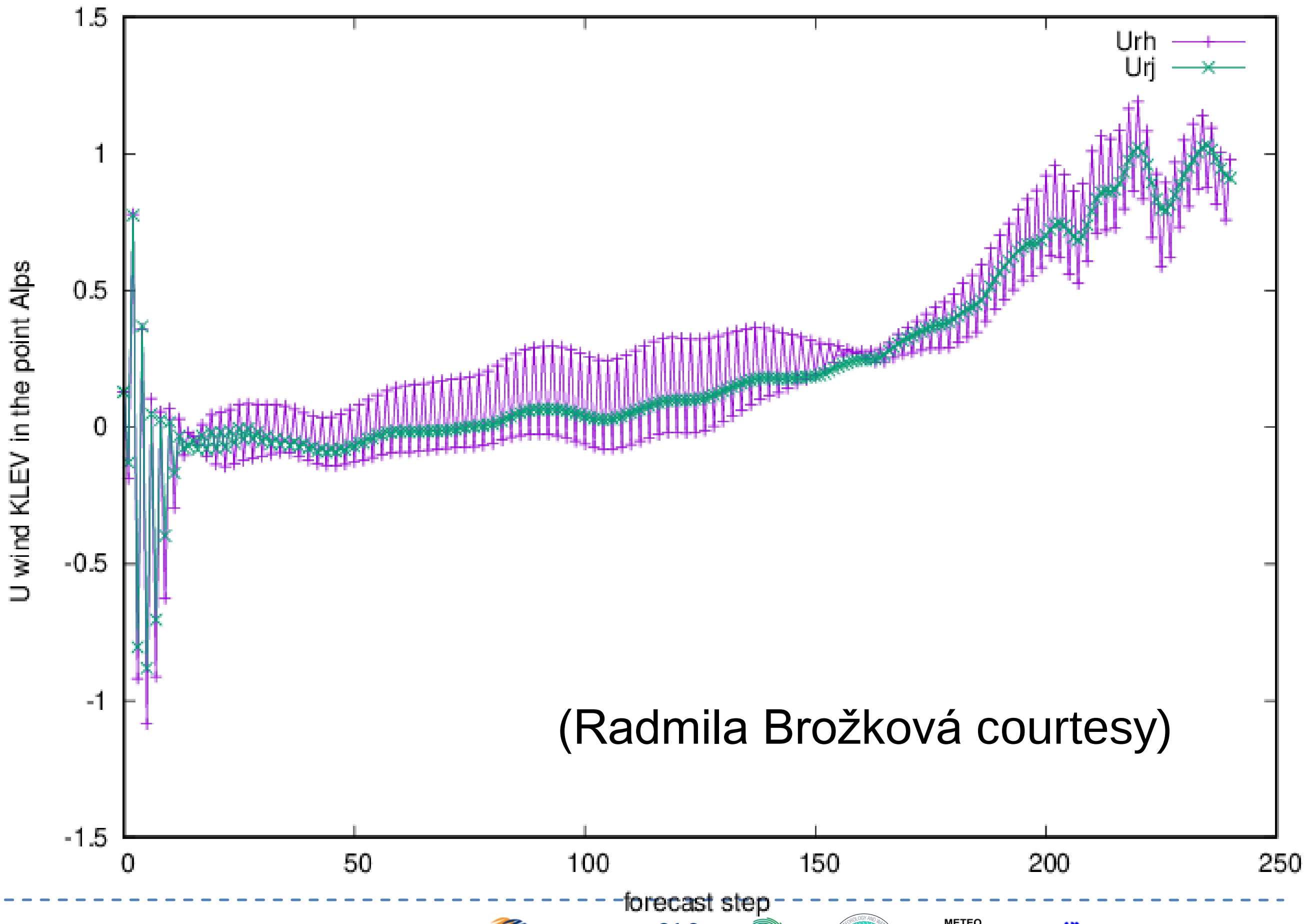
- Using ND4SYS = 1 is dangerous:

ND4SYS = 1

ND4SYS = 2

- Time evolution of U -wind at the surface at one grid point in Alps



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Tests of the new configuration

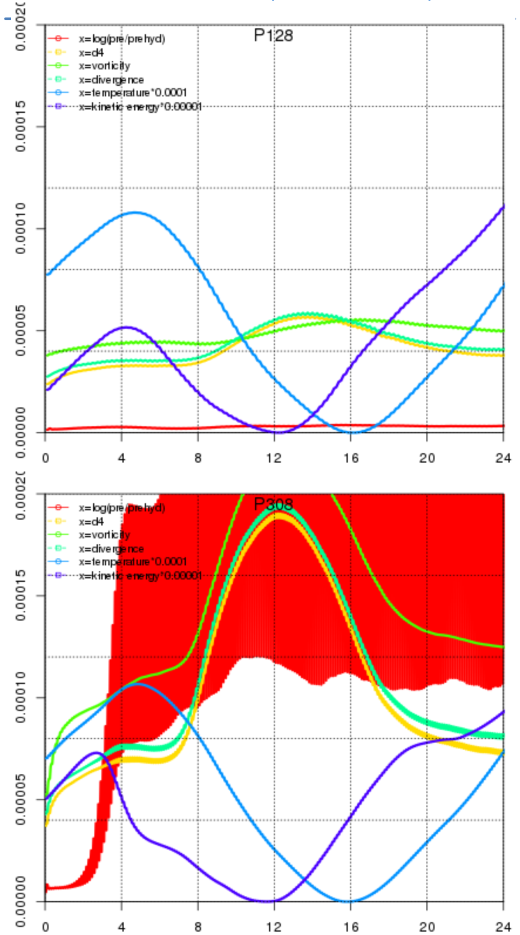
1) temporal evolution of spectral norms

2) kinetic energy spectra and vertical velocity spectra

3) visualization of some fields (vertical velocity, precipitation)

4) objective scores (RMSE, BIAS, STDE)

- compared to previous operational results



How to detect problems

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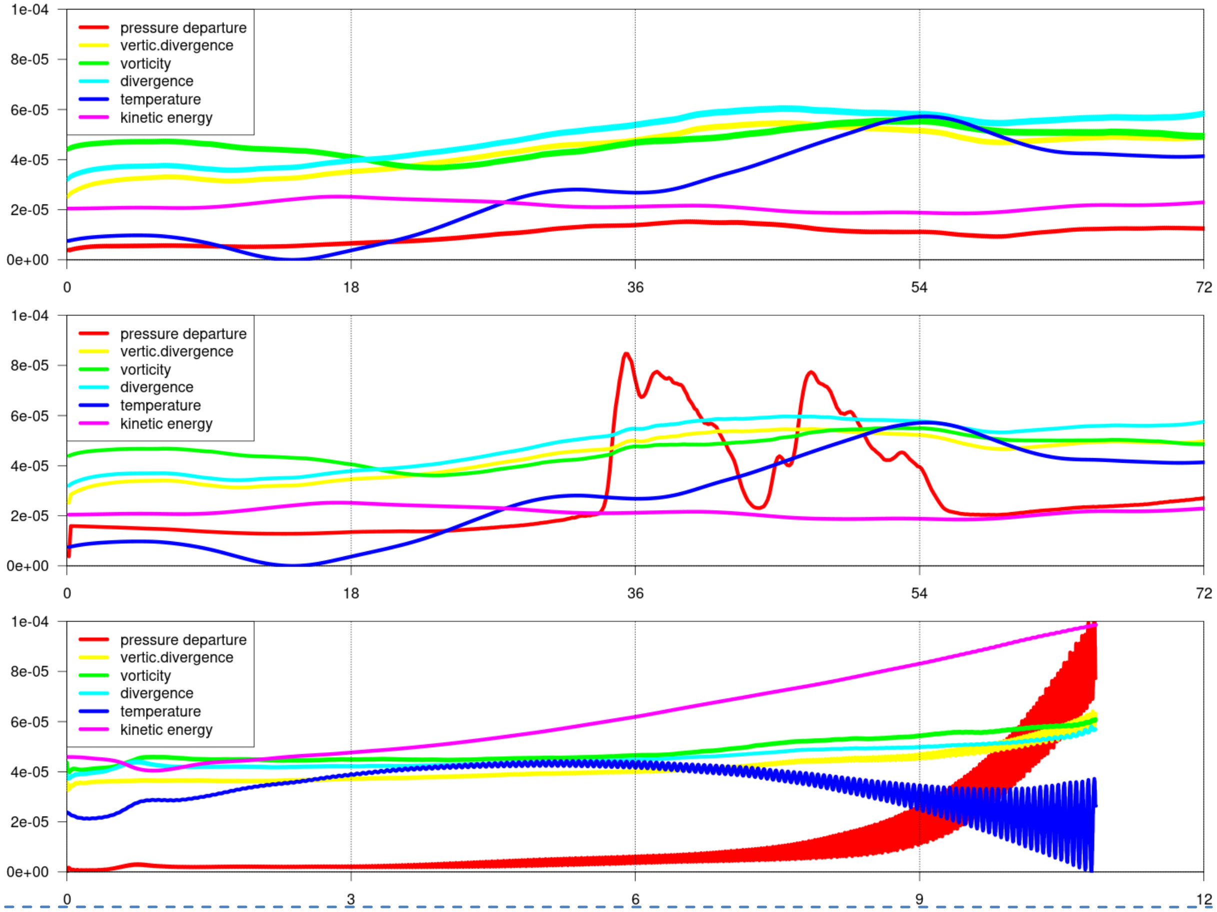
- Evolution of spectral norms



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How to detect problems

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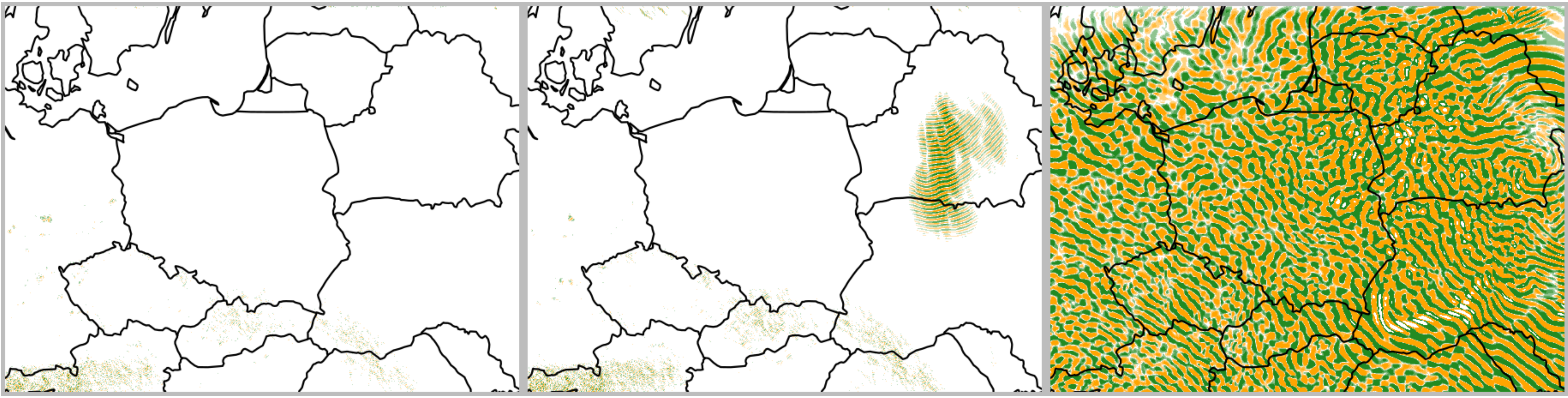
- Check some arrays



- Pressure departure at 20 hPa

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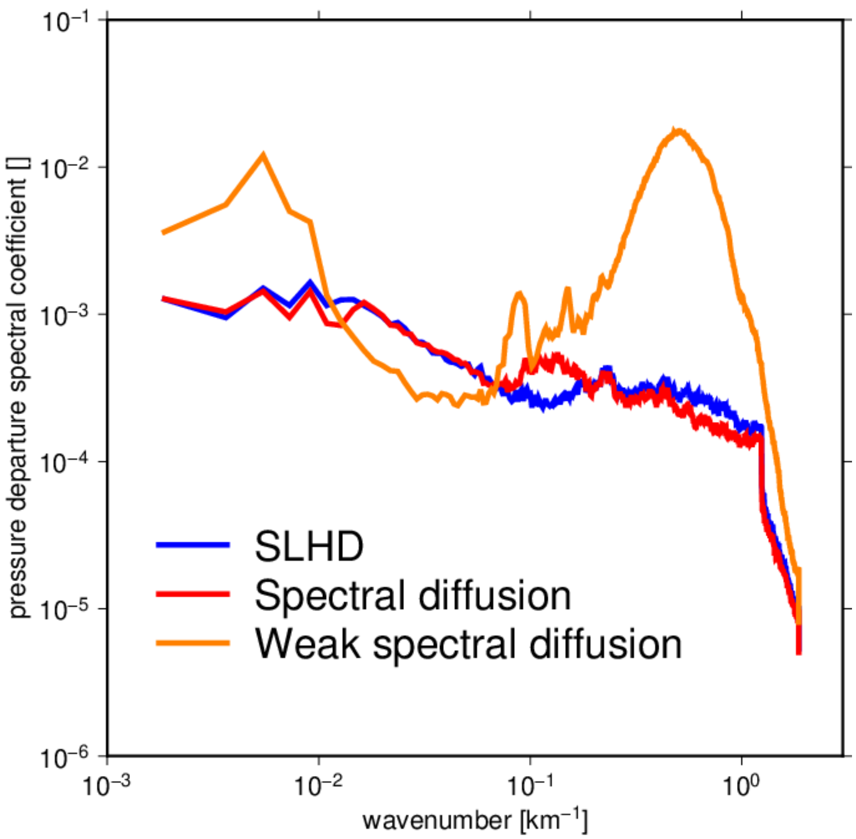
How to detect problems

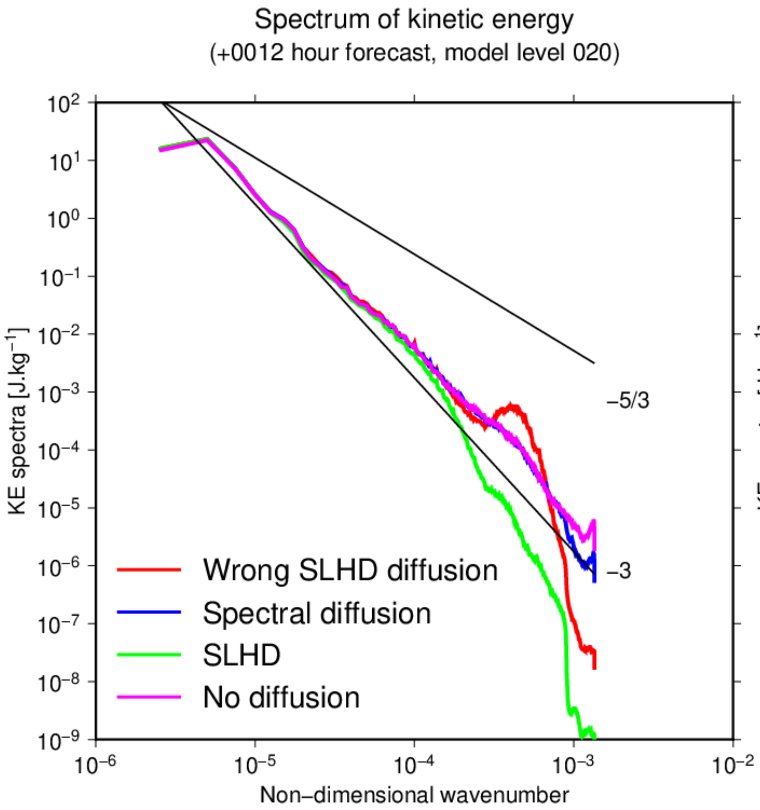
- Arrays spectra

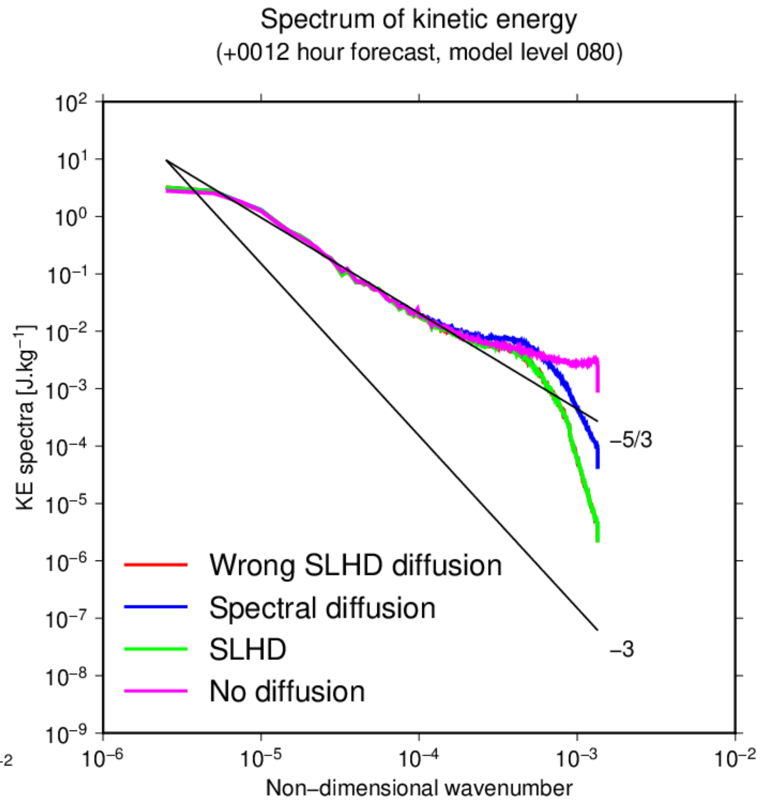


- Pressure departure at 20 hPa

How to detect problems

- Kinetic energy spectra





Summary – an example with SLHD

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```
&NAMDYN                                              &NAMDYNA

LADVF=.T.,           RDAMPDIV=5.,        LGWADV=.T.,         LSLHD_GFL=.T.,
LQMXX=.F.,           RDAMPVOR=5.,        LRDBBC=.F.,         LSLHD_OLD=.F.,
SIPR=90000.,         RDAMPPD=5.,         LNESC=.T.,          LSLHD_XX=.T.,
SITR=350.,           RDAMPQ=20.,         LSETTLS=.F.,        SLHDEPSH=0.016,
SITRA=100.,          RDAMPT=20.,         LNESCT=.F.,         SLHDEPSV=0.,
NSITER=2,            RDAMPVD=20.,        LNESCV=.F.,         SLHDKMAX=6.,
NSPDLAG=3,           RDAMPVORS=10.,      LSETTLST=.T.,       SLHDKMIN=-0.6,
NSVDLAG=3,           RDAMPDIVS=10.,      LSETTLSV=.T.,
NTLAG=3,             RDAMPVDS=15.,       LPC_FULL=.T.,       &NAMGFL
NVLAG=3,             REXPDH=2.,          LPC_CHEAP=.T.,
NWLAG=3,             REXPDHS=6.,         ND4SYS=2,           YXX_NL%LPC=.T.,
VESL=0.,             SDRED=1.,           NDLNPR=1,           YXX_NL%LSLHD=.T.,
XIDT=0.,             SLEVDH=0.5,         NPDVAR=2,
NITMP=5,             SLEVDHS=1.,         NVDVAR=4,            XX stands for a variable
RRDXTAU=123.,
```

Summary – an example without SLHD

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```
&NAMDYN                                           &NAMDYNA

LADVF=.T.,          RDAMPDIV=20.,    LGWADV=.T.,
LQMXX=.F.,          RDAMPVOR=20.,    LRDBBC=.F.,
SIPR=90000.,        RDAMPPD=20.,     LNESC=.T.,
SITR=350.,          RDAMPQ=0.,       LSETTLS=.F.,       SLHDEPSH=0.08,
SITRA=100.,         RDAMPT=0.,       LNESCT=.T.,        SLHDEPSV=0.,
NSITER=2,           RDAMPVD=20.,     LNESCV=.T.,        SLHDKMAX=6.,
NSPDLAG=3,                           LSETTLST=.F.,      SLHDKMIN=-0.6,
NSVDLAG=3,                           LSETTLSV=.F.,
NTLAG=3,                             LPC_FULL=.T.,      &NAMGFL
NVLAG=3,                             LPC_CHEAP=.F.,
NWLAG=3,                             ND4SYS=2,          YXX_NL%LPC=.T.,
VESL=0.,                             NDLNPR=1,          YXX_NL%LSLHD=.F.,
XIDT=0.,                             NPDVAR=2,
NITMP=5,                             NVDVAR=4,           XX stands for a variable
RRDXTAU=205.,
```

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Thank you for your attention.

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