



# Dynamics & Coupling

*2006 fulfilment  
and  
plan for 2007*

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CHMI

# Plan for 2006

Project	Topic	Planned/Fulfilled effort	LACE support
I.	Iterative schemes	0/0	1/1
	Further improvement of NH	1.5/0	
	Diabatic forcing	0/0	
	VFE	3/5	
	BBC	-/0.5	
II.	Studies linked to high resolution	0/0	1/1 1/1
	Horizontal pressure gradient term	0.5/0.5	
	HD above slopes	0/0	
	RUBC	0/0	
	Phys. coupling to dynamics	1.5/1.5	
	Spline interpolation for SL	1.5/1.75	
	TL/AD of the plane SL	5/6	
	SLHD	-/1	
III.	3D diagnostic tool for coupling	1.5/1.5	1/1
	Spectral coupling	0/0	
	<i>Total:</i>	<b>14.5/17.75</b>	<b>4/4</b>

# Vertical Finite Element scheme

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- First version of VFE implemented to the code. It is stable, efficient (2-3 % extra CPU) but (for the moment) noisy.
- Plan to implement VFE without major revision of the NH core.

# Vertical Finite Element scheme

NLNH02 test  
 perturbation of V-wind [m/s], NSTEP = +0500

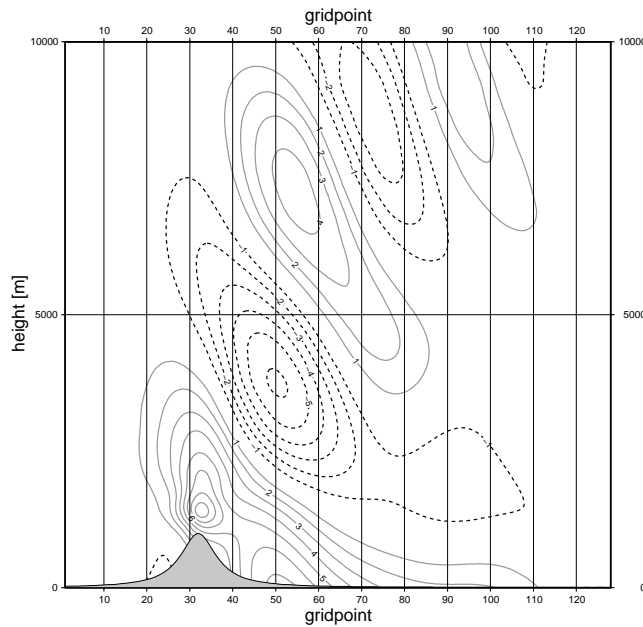
```

TSTEP test: 5 2TL ICI NESC scheme NSITER=1
LVERTFE      =FALSE
LVFE_LAPL_FD =FALSE
LVFE_UVH_FD  =FALSE
LVFE_GW_FD   =FALSE
NVSCH        =3
NVDER        =3
  
```

NLNH02 test  
 perturbation of V-wind [m/s], NSTEP = +0500

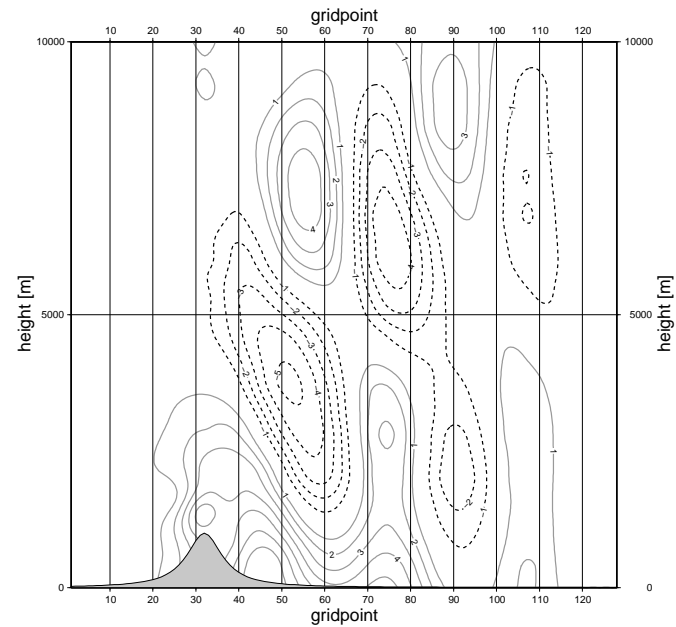
```

TSTEP test: 5 2TL ICI NESC scheme NSITER=1
LVERTFE      =TRUE
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LVFE_UVH_FD  =FALSE
LVFE_GW_FD   =FALSE
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NVDER        =3
  
```



GM 2006 Jul 4 11:30:31 experiment: VFES

min: -6.1452  
 max: 8.6435  
 step: 1



GM 2006 Jun 22 08:23:15 experiment: VFES

min: -5.2998  
 max: 7.7414  
 step: 1

## FD scheme versus full VFE



# Vertical Finite Element scheme

NLNH02 test  
 perturbation of V-wind [m/s], NSTEP = +0500

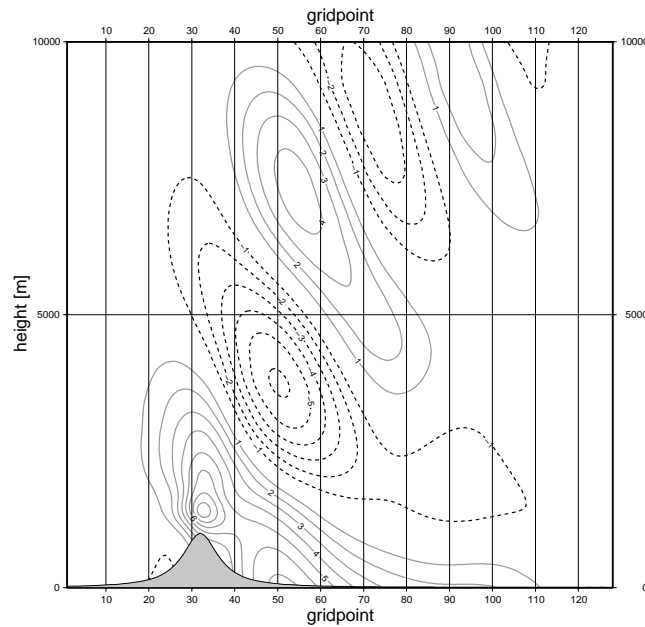
```

TSTEP test: 5 2TL ICI NESC scheme NSITER=1
LVERTFE      =FALSE
LVFE_LAPL_FD =FALSE
LVFE_UVH_FD  =FALSE
LVFE_GW_FD   =FALSE
NVSCH        =3
NVDER        =3
  
```

NLNH02 test  
 perturbation of V-wind [m/s], NSTEP = +0500

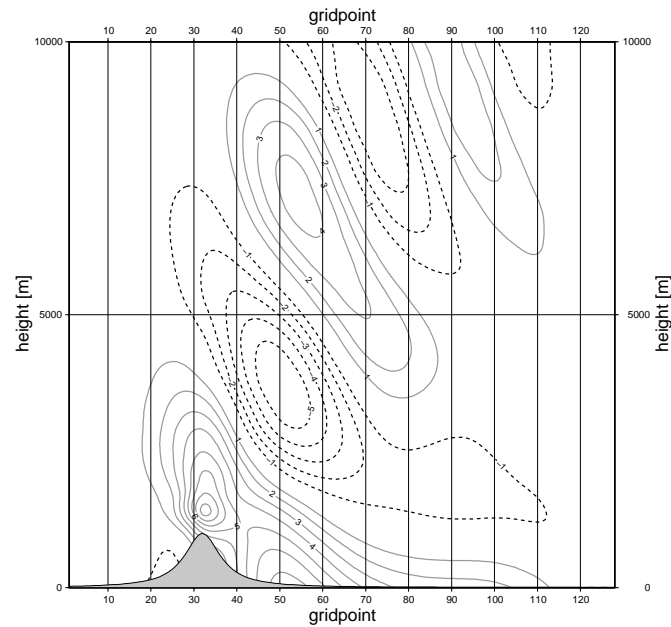
```

TSTEP test: 5 2TL ICI NESC scheme NSITER=1
LVERTFE      =TRUE
LVFE_LAPL_FD =FALSE
LVFE_LAPL_BC_FD =TRUE
LVFE_UVH_FD  =TRUE
LVFE_GW_FD   =TRUE
NVSCH        =3
NVDER        =3
  
```



GM 2006 Jul 4 11:30:31 experiment: VF09

min: -6.1452  
 max: 8.6435  
 step: 1



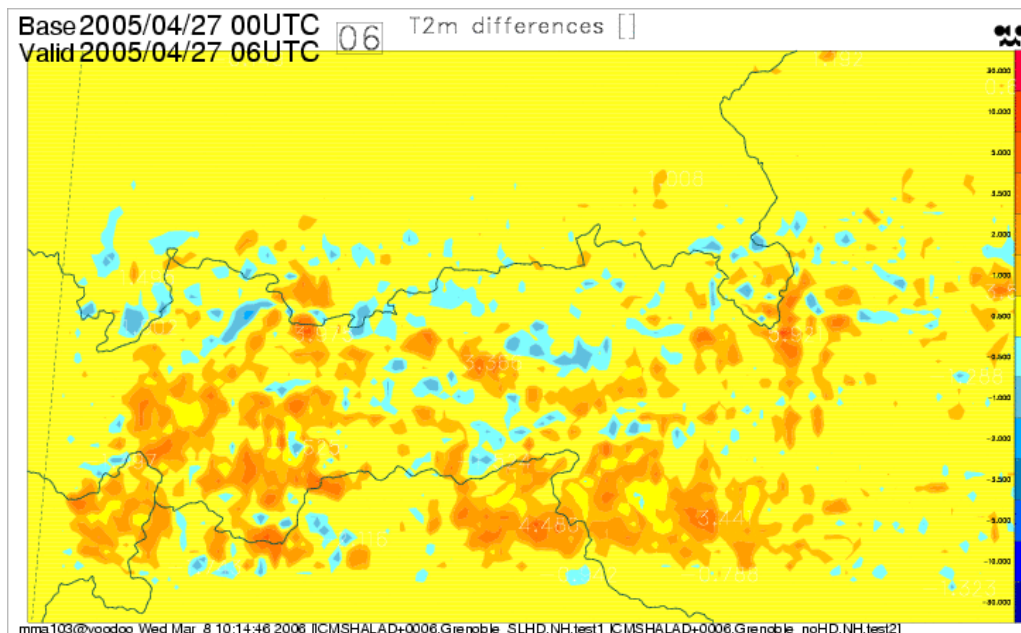
GM 2006 Jul 4 11:30:38 experiment: VF12

min: -5.8633  
 max: 8.4249  
 step: 1

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

# BBC

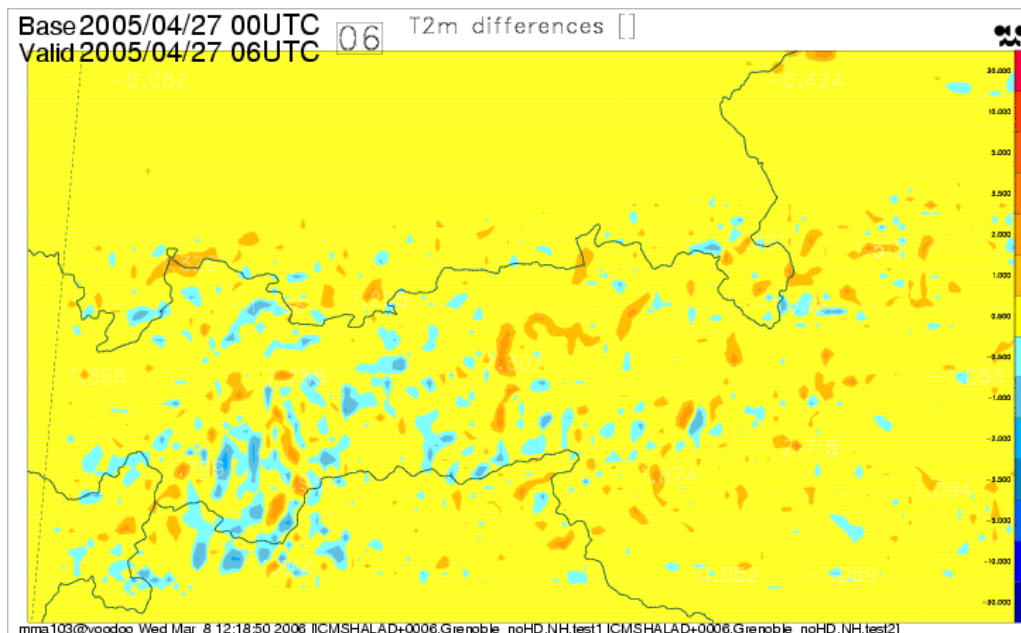
## T2m differences (model - noHD)



- Original SLHD tuning

# BBC

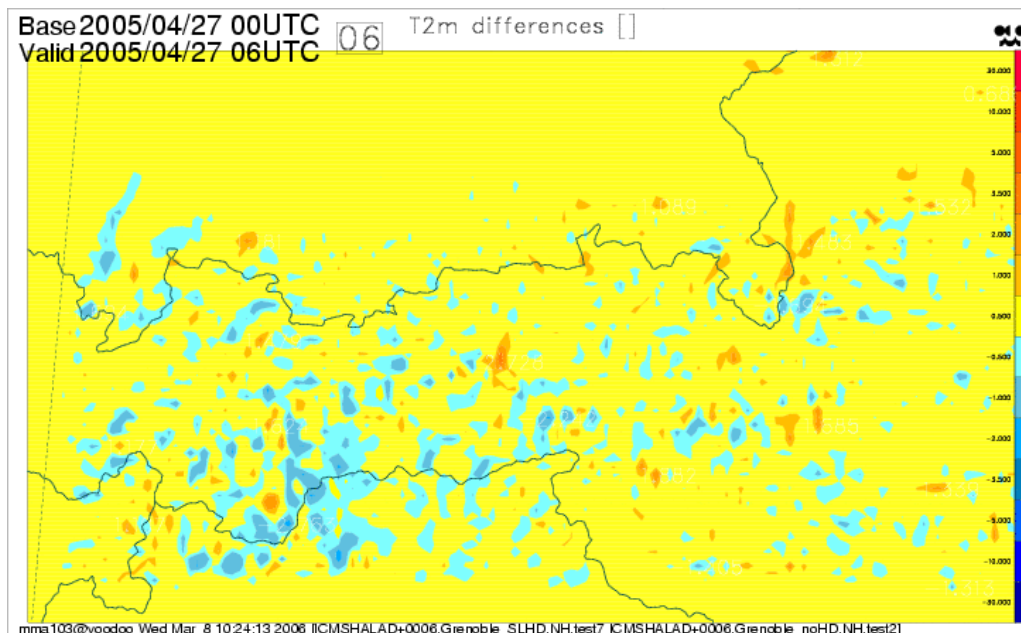
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- Original SLHD tuning
- Spectral diffusion

# BBC

## T2m differences (model - noHD)

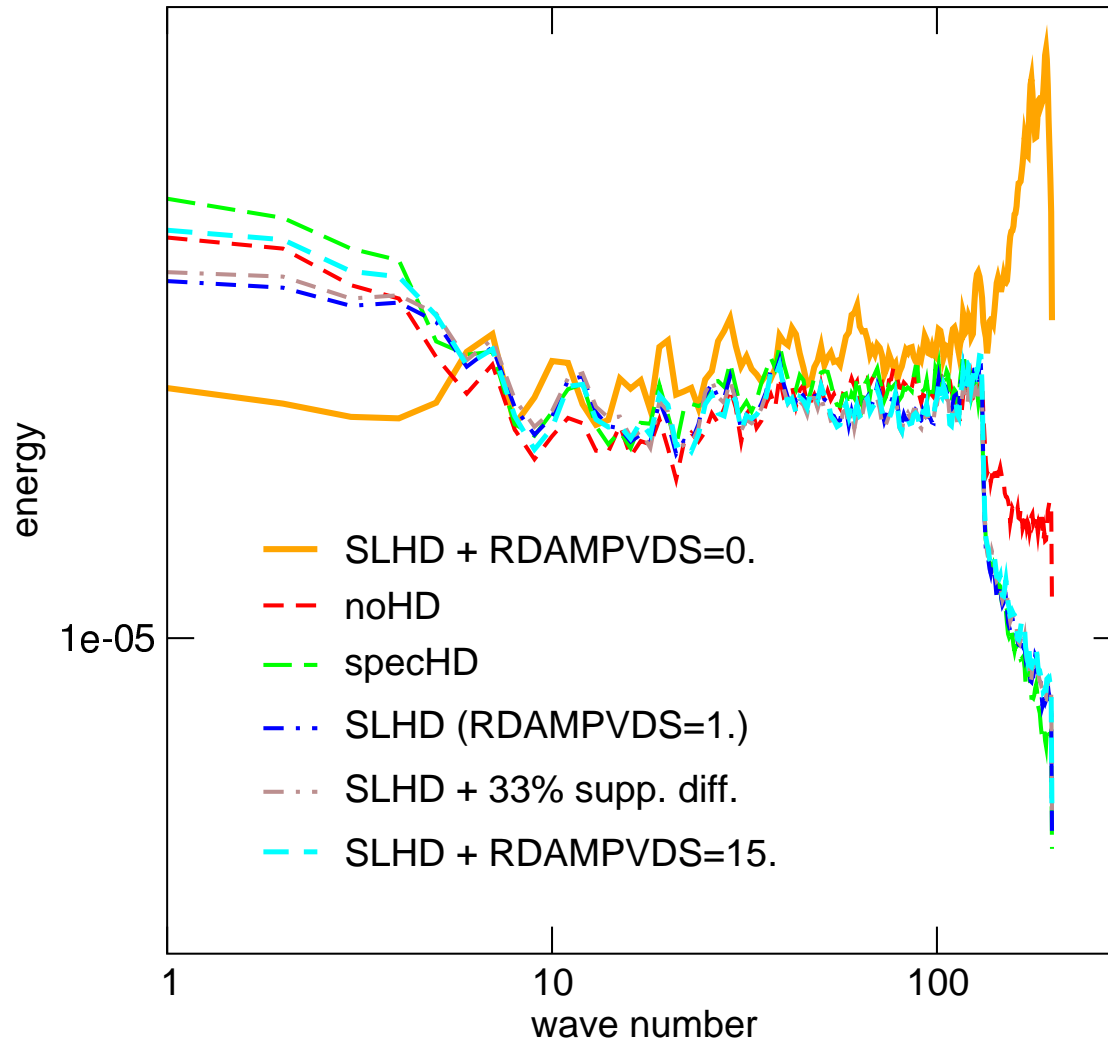


- Original SLHD tuning
- Spectral diffusion
- New SLHD tuning

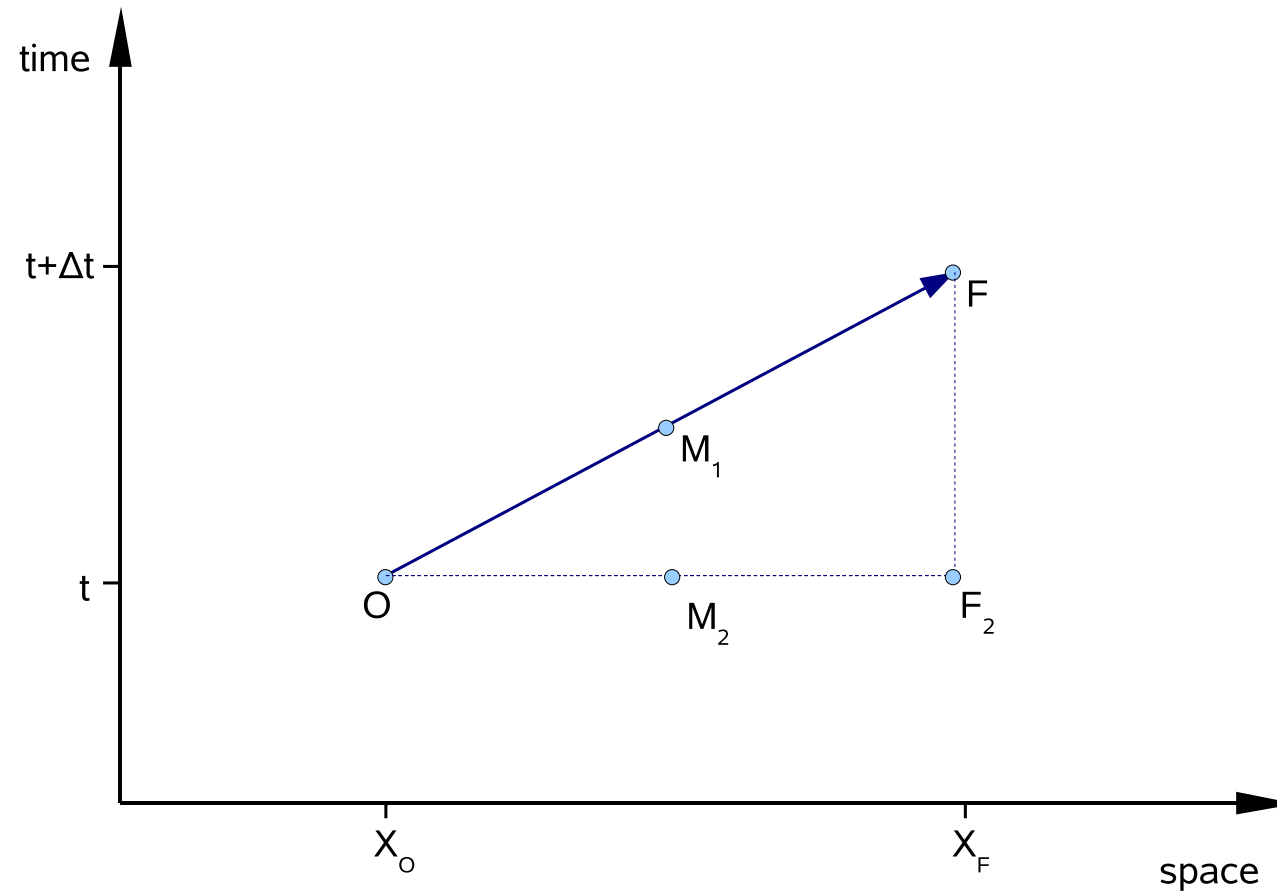
# BBC - II.

## vertical divergence spectra

43th model level (the lowest)

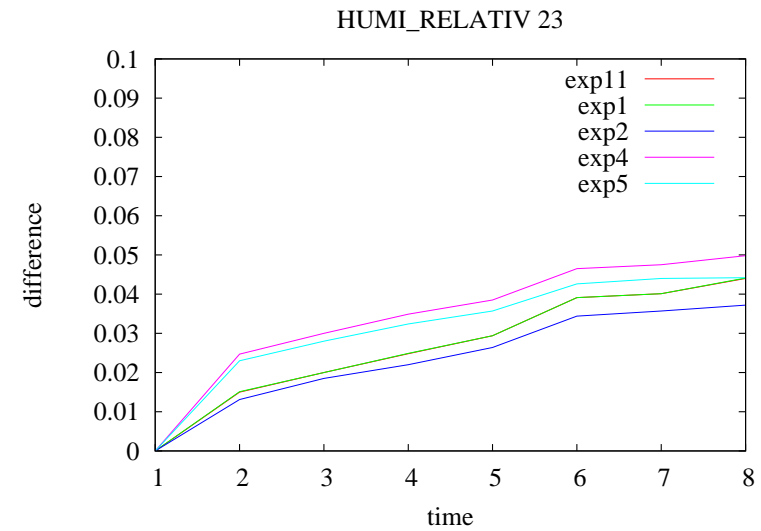
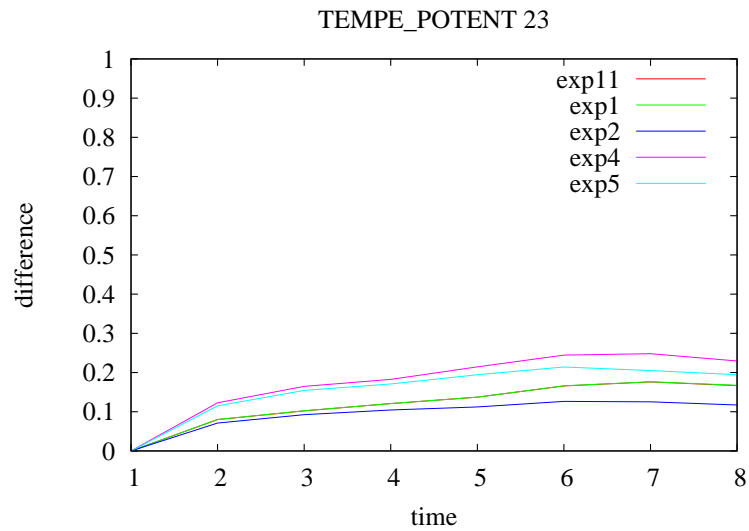


# Phys-dyn coupling



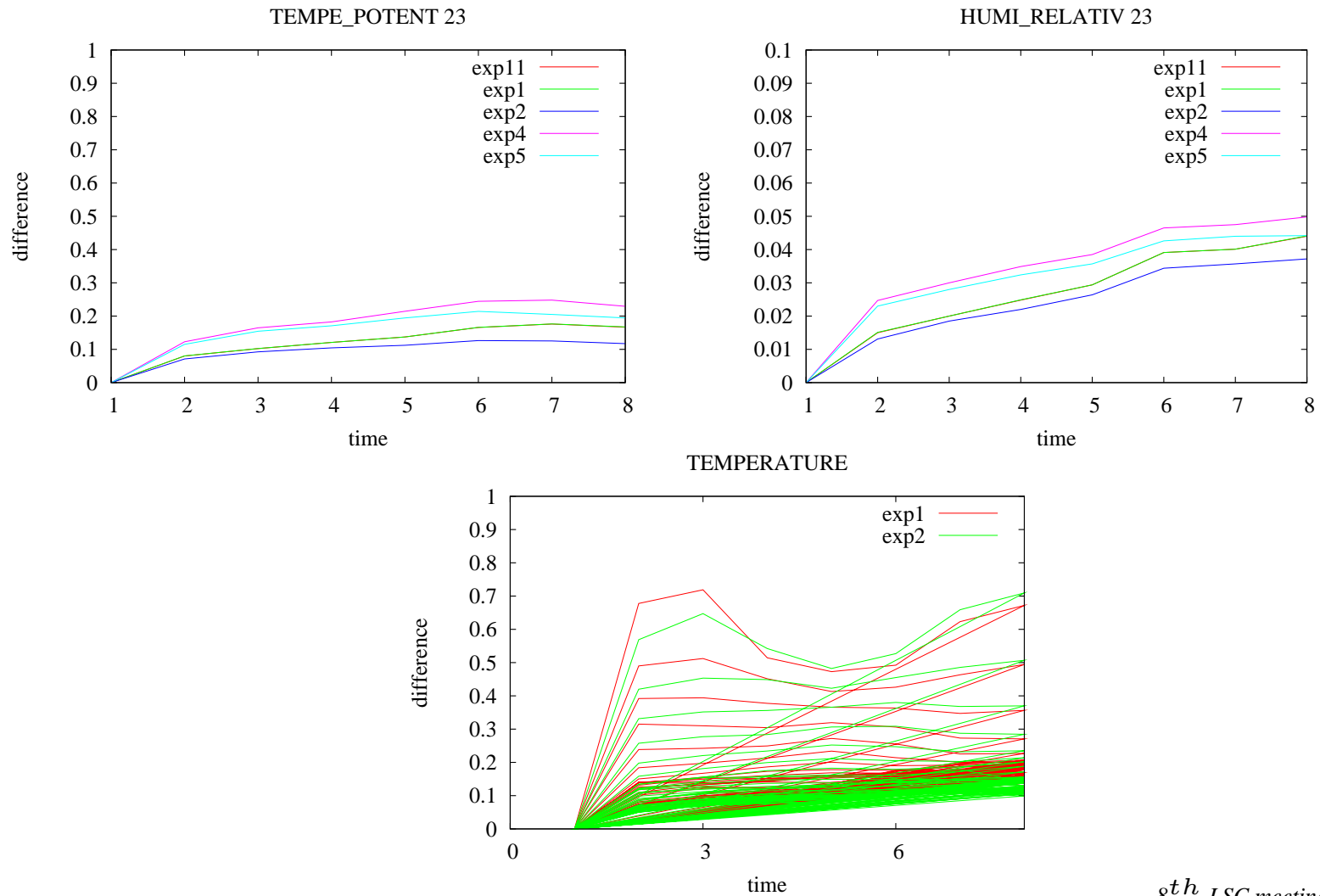
# Phys-dyn coupling II

$$dev = \sqrt{(F_{\Delta t=360} - F_{\Delta t=30})}$$



# Phys-dyn coupling II

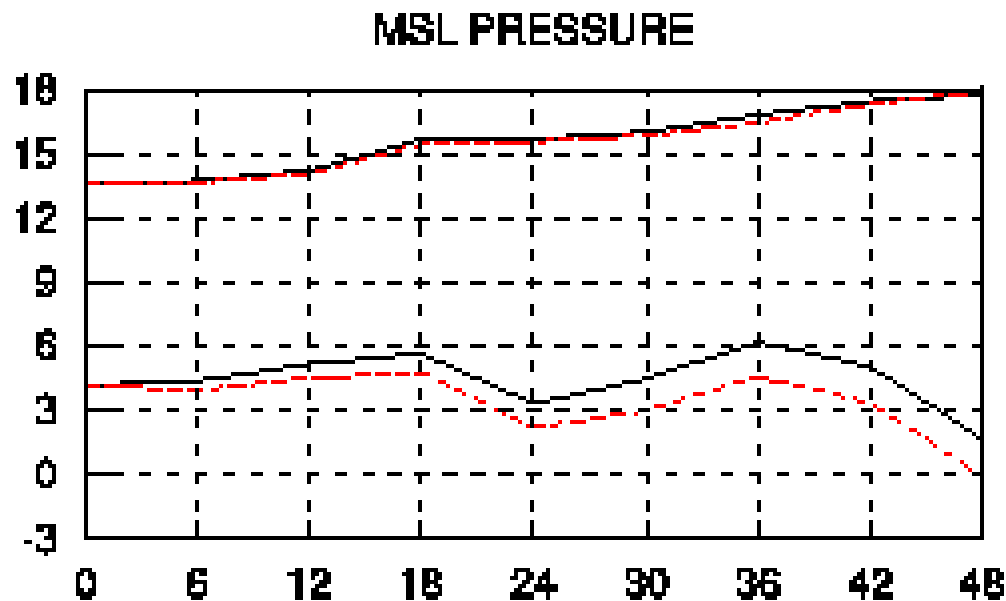
$$dev = \sqrt{(F_{\Delta t=360} - F_{\Delta t=30})}$$





# New interpolators for SL

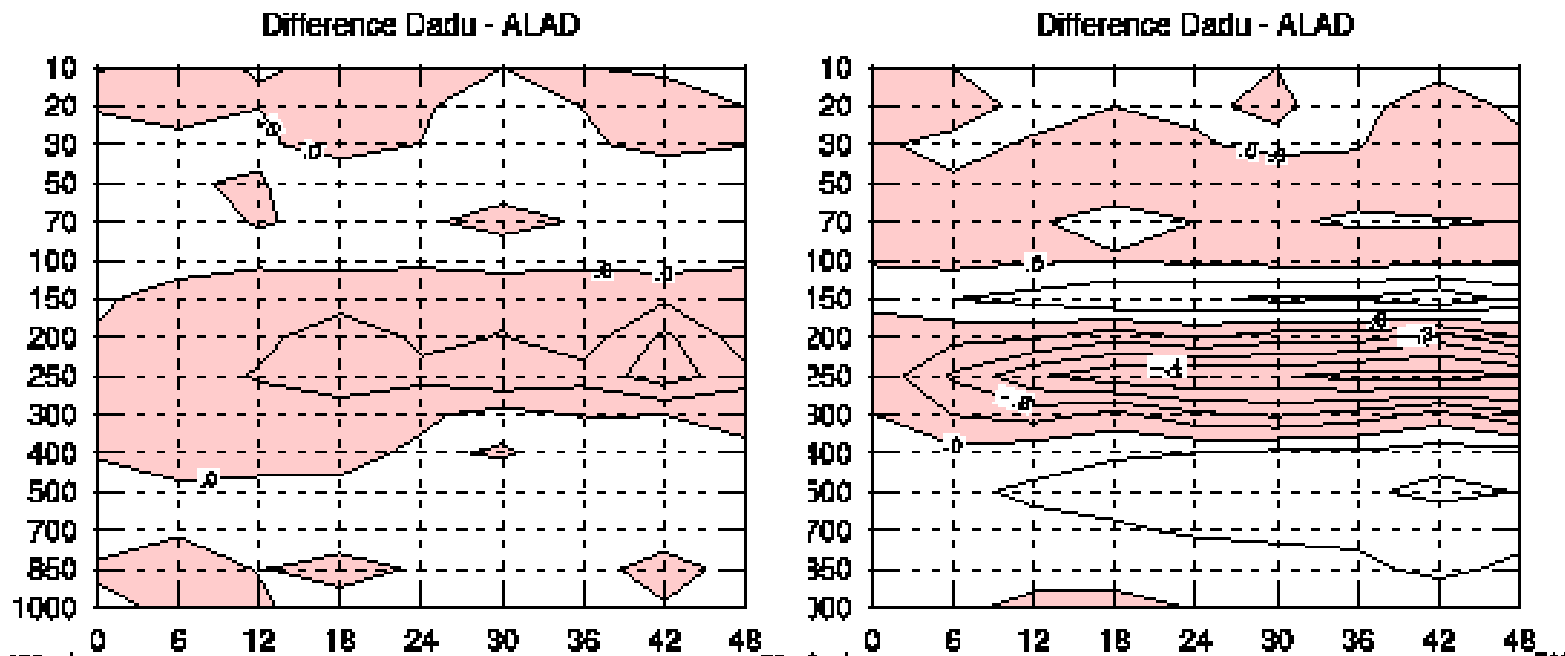
**Motivation:** SLHD affects conservative properties of the model  $\Rightarrow$  need to an improvement of the SL interpolators accuracy.



MSL pressure RMSE and BIAS for 15 days of parallel run

# New interpolators for SL

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



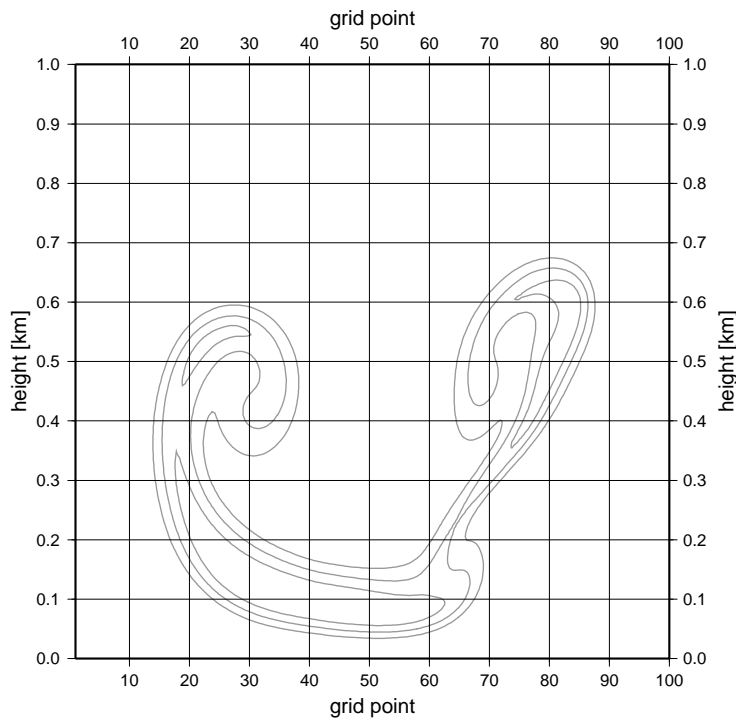
temperature RMSE and BIAS for 15 days of parallel run

# New interpolators for SL

## Bubble test, after 10 minutes

WARM + COLD BUBBLE TEST  
perturbation of potential temperature [K], NSTEP = +0120

```
init_102_wcb2_eta, eta-coordinate
master_al29t2mx1_02_sx6, (A1, A2) = (0, 0), .NOT.LQM
NH sl2tl, (NPDVAR, NVDVAR) = (2, 3), NSITER = 1, LPC_FULLL, LPC_NESC, LGWADV
.NOT.LQM[x], .NOT.LQMH[x], LRSPLINE_[x], N[x]LAG = 3
TSTEP = 5.0 s
DELY = 10 m DELZ = 10 m
P00 = 101325 Pa THETA00 = 300 K
SIPR = 90000 Pa SITR = 350 K SITRA = 100 K
RRDXTAU = 0
```



- Linear

GMT 2006 Aug 4 18:46:16 experiment: C010

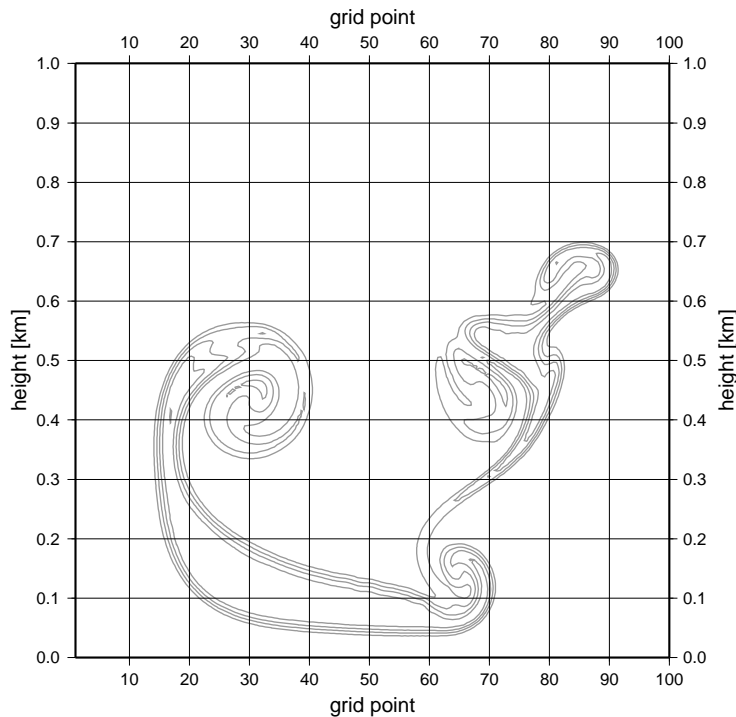
min: -10.645  
max: 1.8519  
step: 0.12

# New interpolators for SL

## Bubble test, after 10 minutes

WARM + COLD BUBBLE TEST  
perturbation of potential temperature [K], NSTEP = +0120

```
init_102_wcb2_eta, eta-coordinate
master_al29t2mx1_02_sx6, (A1, A2) = (-1/3, 1/2), .NOT.LQM
NH sl2tl, (NPDVAR, NVDVAR) = (2, 3), NSITER = 1, LPC_FULLL, LPC_NESC, LGWADV
.NOT.LQM[x], .NOT.LQMH[x], LRSPLINE_[x], N[x]LAG = 3
TSTEP = 5.0 s
DELY = 10 m DELZ = 10 m
P00 = 101325 Pa THETA00 = 300 K
SIPR = 90000 Pa SITR = 350 K SITRA = 100 K
RRDXTAU = 0
```



- Linear
- Lagrangian cubic

GMT 2006 Aug 4 15:46:50 experiment: C000

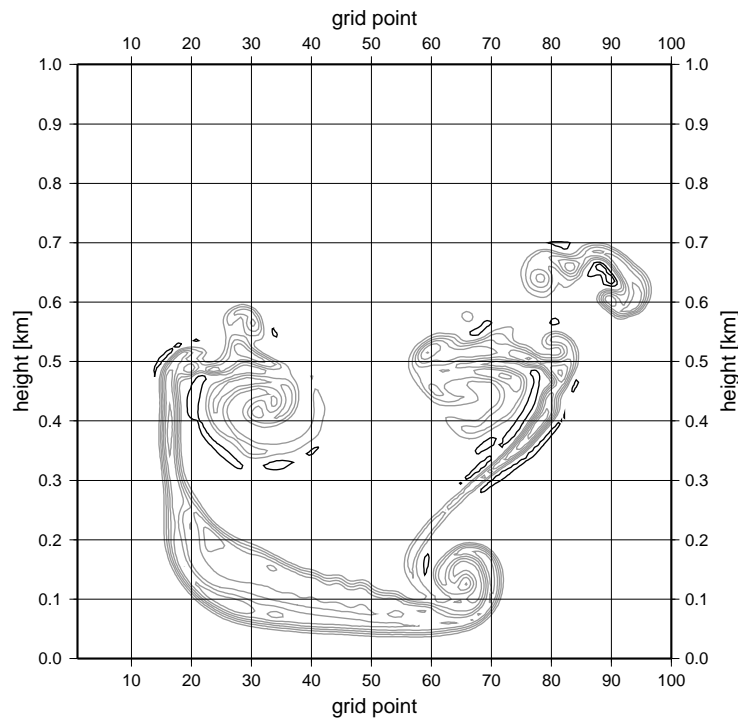
min: -3.7963  
max: 2.34  
step: 0.12

# New interpolators for SL

## Bubble test, after 10 minutes

WARM + COLD BUBBLE TEST  
perturbation of potential temperature [K], NSTEP = +0120

```
init_102_wcb2_eta, eta-coordinate
master_al29t2mx1_02_sx6, (A1, A2) = (-7/15, 4/5), .NOT.LQM
NH sl2tl, (NPDVAR, NVDVAR) = (2, 3), NSITER = 1, LPC_FULL, LPC_NESC, LGWADV
.NOT.LQM[x], .NOT.LQMH[x], LRSPLINE_[x], N[x]LAG = 3
TSTEP = 5.0 s
DELY = 10 m DELZ = 10 m
P00 = 101325 Pa THETA00 = 300 K
SIPR = 90000 Pa SITR = 350 K SITRA = 100 K
RRDXTAU = 0
```



- Linear
- Lagrangian cubic
- Splines

GMT 2006 Aug 5 15:31:48 experiment: C004

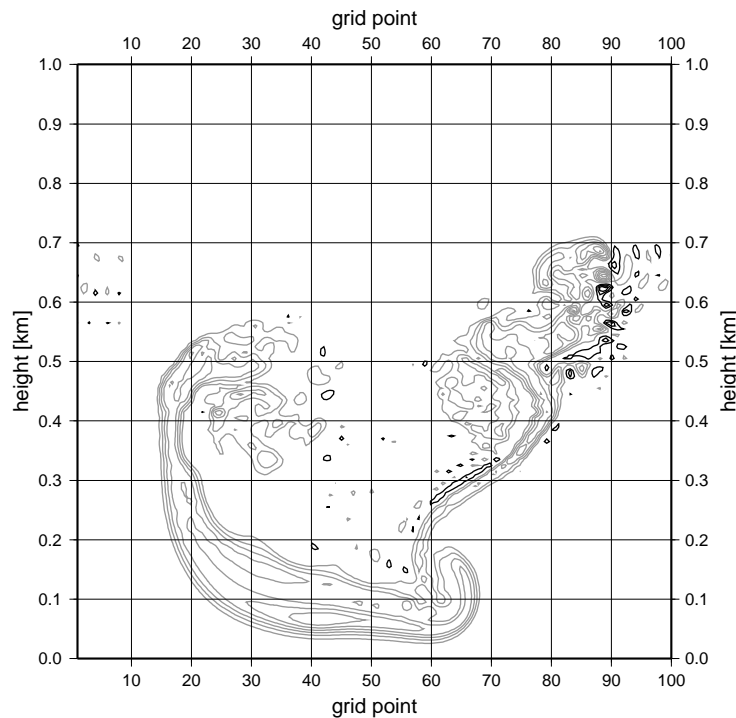
min: -9.616  
max: 12.39  
step: 0.12

# New interpolators for SL

## Bubble test, after 10 minutes

WARM + COLD BUBBLE TEST  
perturbation of potential temperature [K], NSTEP = +0600

```
init_102_wcb2_eta, eta-coordinate  
master_al29t2mx1_02_sx6  
NH euler, (NPDVAR, NVDVAR) = (2, 3), NSITER = 1, LPC_OLD  
TSTEP = 1.0 s  
DELY = 10 m DELZ = 10 m  
P00 = 101325 Pa THETA00 = 300 K  
SIPR = 90000 Pa SITR = 250 K SITRA = 250 K  
RRDXTAU = 0
```



- Linear
- Lagrangian cubic
- Splines
- Eulerian adv.

GMT [2006 Aug 4 20:05:50] experiment: C900

min: -62.434  
max: 16.339  
step: 0.12

# New interpolators for SL

Family of two parametric cubic interpolators

$$\mathbf{F}(\mathbf{x}, \mathbf{y}) = \mathbf{w}_0(\mathbf{x})\mathbf{y}_0 + \mathbf{w}_1(\mathbf{x})\mathbf{y}_1 \\ + \mathbf{w}_1(1 - \mathbf{x})\mathbf{y}_2 + \mathbf{w}_0(1 - \mathbf{x})\mathbf{y}_3$$

where

$$\mathbf{w}_0(\mathbf{x}) = \mathbf{a}_1\mathbf{x} + \mathbf{a}_2\mathbf{x}^2 - (\mathbf{a}_1 + \mathbf{a}_2)\mathbf{x}^3$$

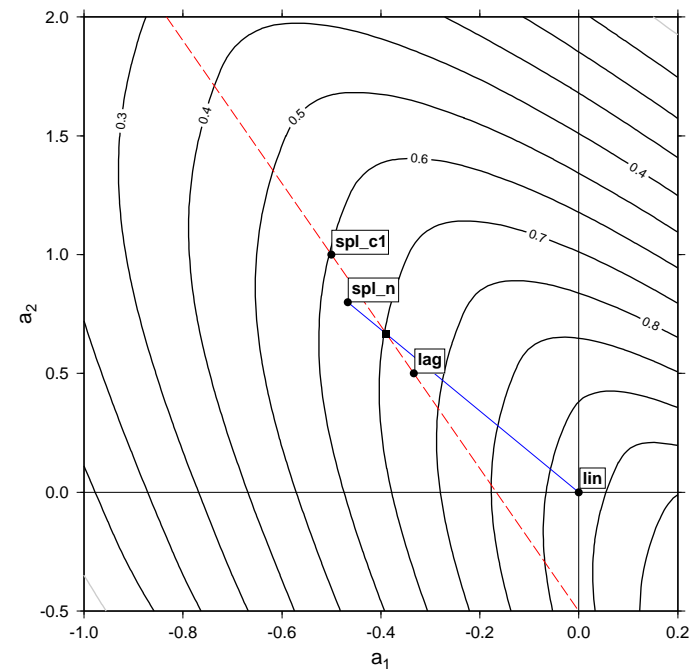
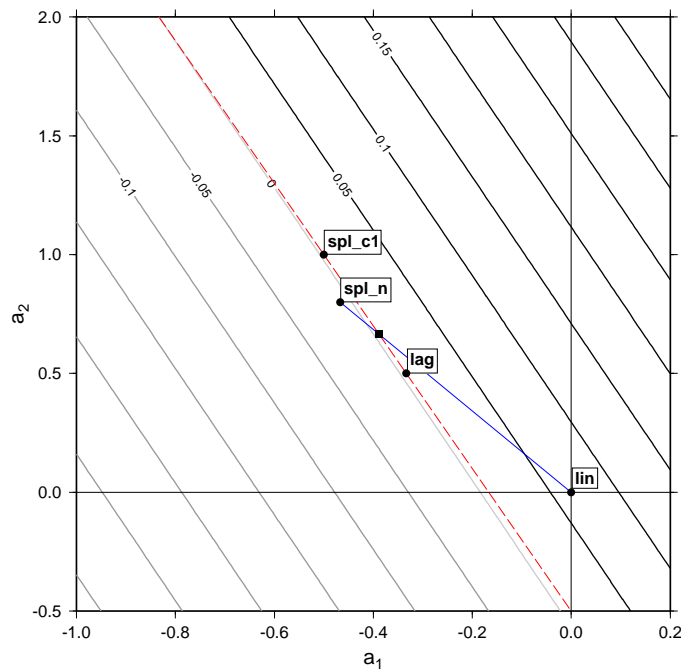
$$\mathbf{w}_1(\mathbf{x}) = 1 + (\mathbf{a}_2 - 1)\mathbf{x} - (3\mathbf{a}_1 + 4\mathbf{a}_2)\mathbf{x}^2 + \\ 3(\mathbf{a}_1 + \mathbf{a}_2)\mathbf{x}^3$$

# 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

## Convergence for the TL code (e501):

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

	Eulerian advection $\Delta t=120s$	SL advection $\Delta t=450s$
$\lambda = 0$	RAT = 0.9685219082957116E+00	RAT = 0.1094034387101322E+01
$\lambda = -1$	RAT = 0.9970618603595810E+00	RAT = 0.1008012195504008E+01
$\lambda = -2$	RAT = 0.9997073040468342E+00	RAT = 0.1002141025110223E+01
$\lambda = -3$	RAT = 0.9999707398884352E+00	RAT = 0.1000160788422592E+01
$\lambda = -4$	RAT = 0.9999970679271253E+00	RAT = 0.1000099605664519E+01
$\lambda = -5$	RAT = 0.9999995490240665E+00	RAT = 0.1000001139215519E+01
$\lambda = -6$	RAT = 0.9999987045356886E+00	RAT = 0.1000001847670018E+01
$\lambda = -7$	RAT = 0.9999936488857756E+00	RAT = 0.1000041939684409E+01
$\lambda = -8$	RAT = 0.9999533728917936E+00	RAT = 0.1000246087384355E+01
$\lambda = -9$	RAT = 0.9991377690586460E+00	RAT = 0.9994838411148169E+00
$\lambda = -10$	RAT = 0.9970808134568164E+00	RAT = 0.1032182685987080E+01

# TL/AD of the ALADIN SL

## Test of the adjoint code (e401):

### Eulerian advection (1 hour, $\Delta t = 120$ s)

```
TEST OF THE ADJOINT
      12345678901234567890
< F(X) , Y > = -.90189924198410820200E-02
< X , F*(Y) > = -.90189924198410612030E-02
THE DIFFERENCE IS      10.395 TIMES THE ZERO OF THE MACHINE
```

### SL advection (1 hour, $\Delta t = 120$ s)

```
TEST OF THE ADJOINT
      12345678901234567890
< F(X) , Y > = -.66041517403842070130E-02
< X , F*(Y) > = -.66041517403841827300E-02
THE DIFFERENCE IS      16.562 TIMES THE ZERO OF THE MACHINE
```

### SL advection (1 hour, $\Delta t = 360$ s)

```
TEST OF THE ADJOINT
      12345678901234567890
< F(X) , Y > = -.71646146174093533820E-02
< X , F*(Y) > = -.71646146174093447100E-02
THE DIFFERENCE IS      5.452 TIMES THE ZERO OF THE MACHINE
```

# TL/AD of the ALADIN SL

## Adjoint code optimization

- Support for vector platforms
- Vectorization of loops

```
ZPP=0.  
DO JROF = KSTART, KPROF  
...  
ZPP= ZPP+ ZNORDY5 ( JROF ) * PO ( JROF , JLEV )  
...  
ZPP=0.  
ENDDO
```

# TL/AD of the ALADIN SL

## Adjoint code optimization

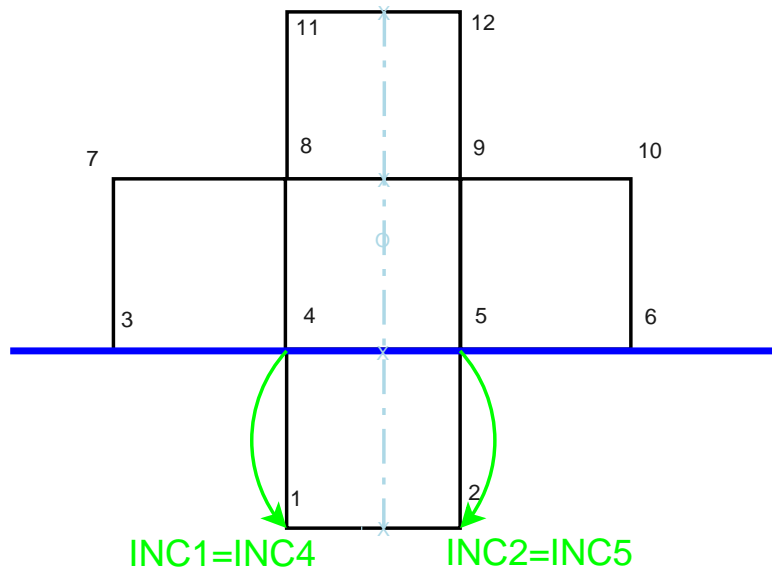
- Support for vector platforms
- Vectorization of loops

```
DO JROF = KSTART, KPROF  
  
...  
ZPP=ZNORDY5 ( JROF ) * PO ( JROF , JLEV )  
  
...  
ENDDO
```

# TL/AD of the ALADIN SL

## Adjoint code optimization

```
DO JINC=ISTART,ISTOP
PSLBUF1( INC(JINC,JROF) ) = &
& PSLBUF1( INC(JINC,JROF) ) + &
& ZINC(JINC,JROF)
ENDDO
```

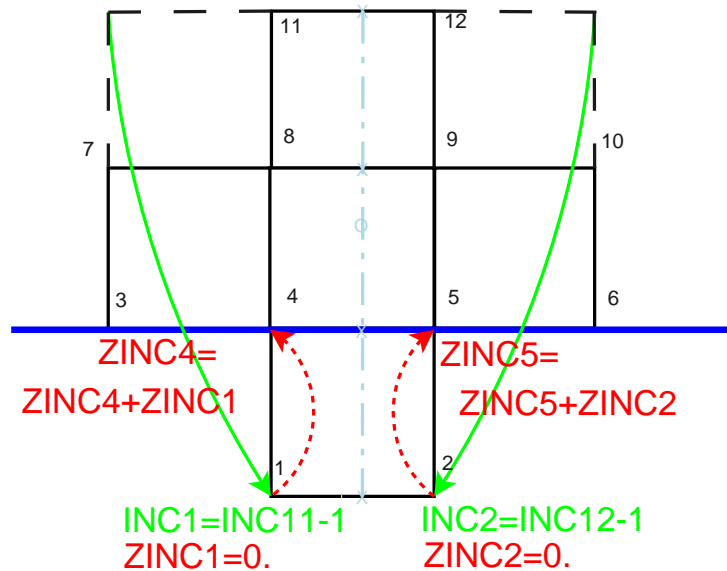


- Support for vector platforms
  - Vectorization of loops
  - Specific LAM development for LVECADIN option

# TL/AD of the ALADIN SL

## Adjoint code optimization

```
DO JINC=ISTART,ISTOP
PSLBUF1( INC(JINC,JROF) ) = &
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```



- Support for vector platforms
  - Vectorization of loops
  - Specific LAM development for LVECADIN option

# TL/AD of the ALADIN SL

## Adjoint code optimization

V.Op.Ratio = 98.814048 %  
VLEN = 225.948825

- Support for vector platforms
  - Vectorization of loops
  - Specific LAM development for LVECADIN option

# TL/AD of the ALADIN SL

## Adjoint code optimization

MPI:

```
LIMP_NOOLAP=.TRUE.,  
LSLONDEM=.TRUE.
```

- **Support for vector platforms**
  - Vectorization of loops
  - Specific LAM development for LVECADIN option
- **Parallel processing**
  - MPI



# TL/AD of the ALADIN SL

## Adjoint code optimization

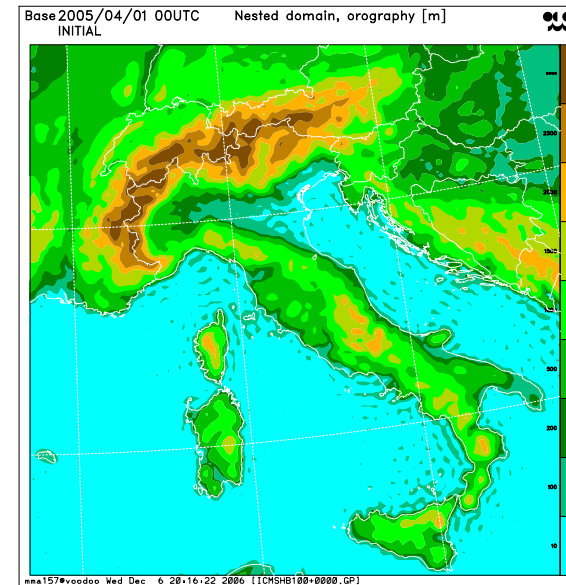
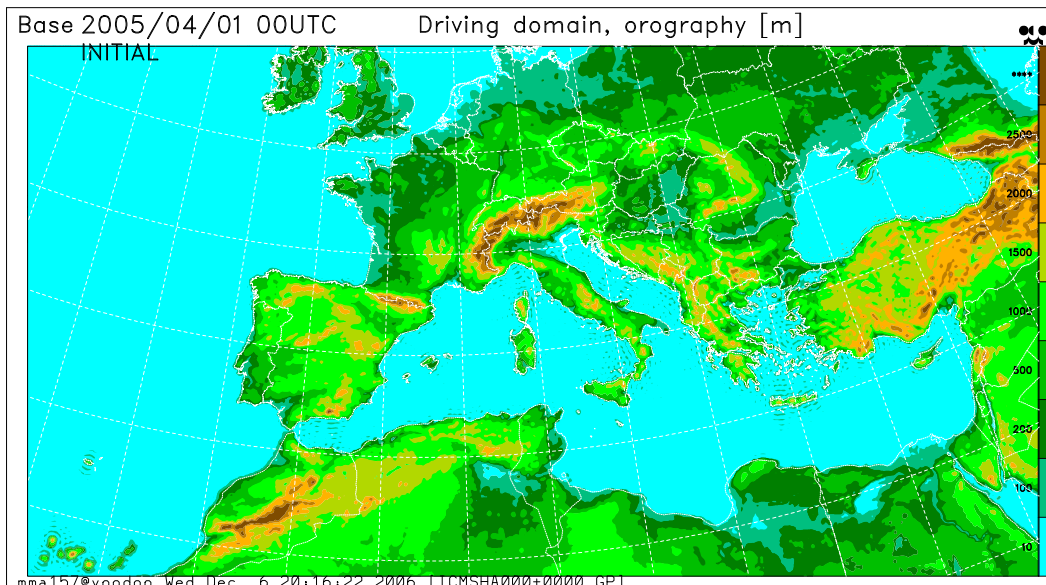
OpenMP:

extra care for YOMOML module  
during compilation

- **Support for vector platforms**
  - Vectorization of loops
  - Specific LAM development for LVECADIN option
- **Parallel processing**
  - MPI
  - OpenMP

# Diagnostic tool for lat. coupling

- Based on perfect model approach (Elía et al., 2002) using the same LAM on two domains with the same resolution and matching grid-points.



# Diagnostic tool for lat. coupling

- Based on perfect model approach (Elía et al., 2002) using the same LAM on two domains with the same resolution and matching grid-points.
- Jump in resolution between driving and nested LAM is simulated by spectral filtering.

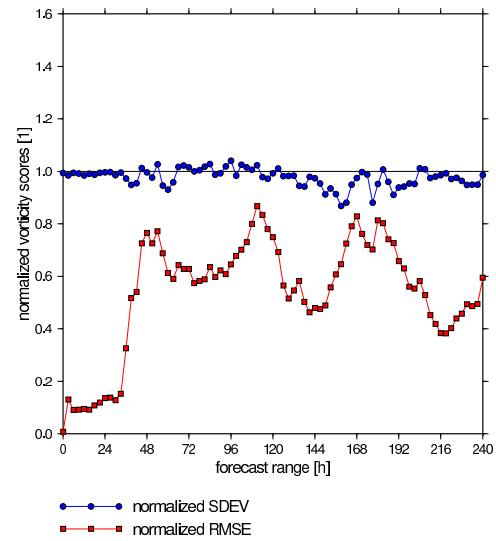
# Diagnostic tool for lat. coupling

- Based on perfect model approach (Elía et al., 2002) using the same LAM on two domains with the same resolution and matching grid-points.
- Jump in resolution between driving and nested LAM is simulated by spectral filtering.
- Performance of coupling is judged according 10 days normalized RMSE difference (from reference solution ) of vorticity field at 500 hPa.

# Diagnostic tool for lat. coupling

Time evolution of vorticity scores at 500 hPa level

## Tests of Davies relaxation scheme



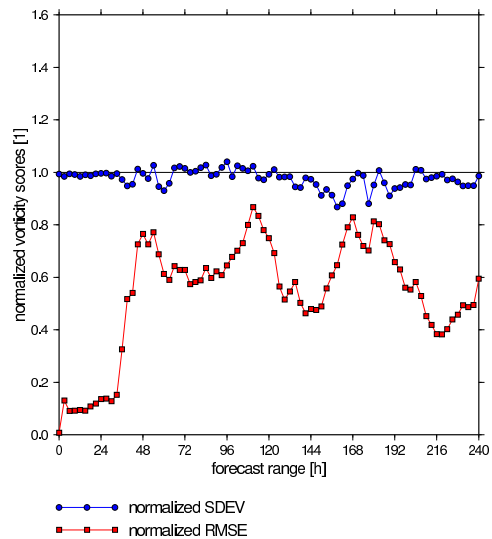
GMT 2006 Dec 7 09:28:41 #100-400

# Diagnostic tool for lat. coupling

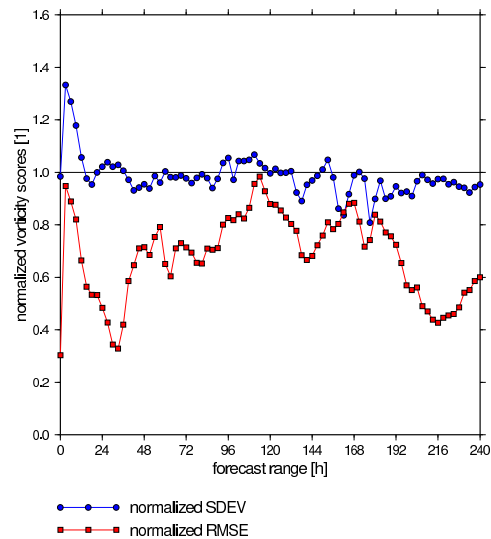
Time evolution of vorticity scores at 500 hPa level

Time evolution of vorticity scores at 500 hPa level

## Tests of Davies relaxation scheme



GMT 2006 Dec 7 09:38:41 #300-400



GMT 2006 Dec 7 09:38:45 #300-400

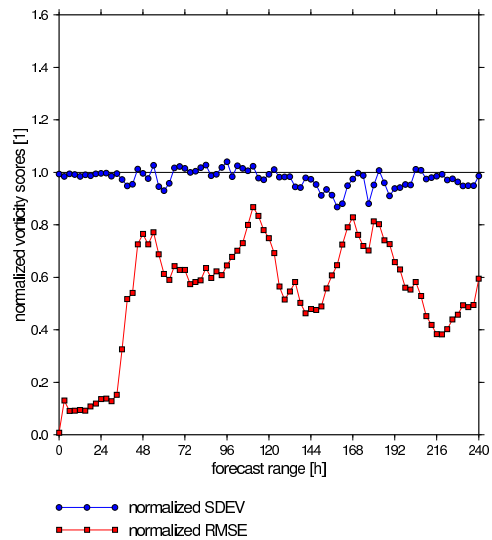
# Diagnostic tool for lat. coupling

Time evolution of vorticity scores at 500 hPa level

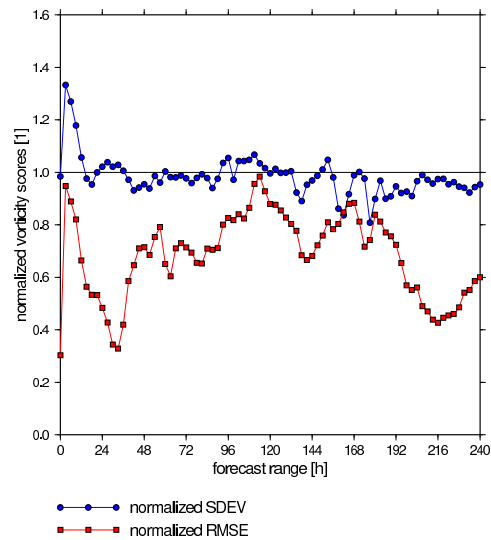
Time evolution of vorticity scores at 500 hPa level

Time evolution of vorticity scores at 500 hPa level

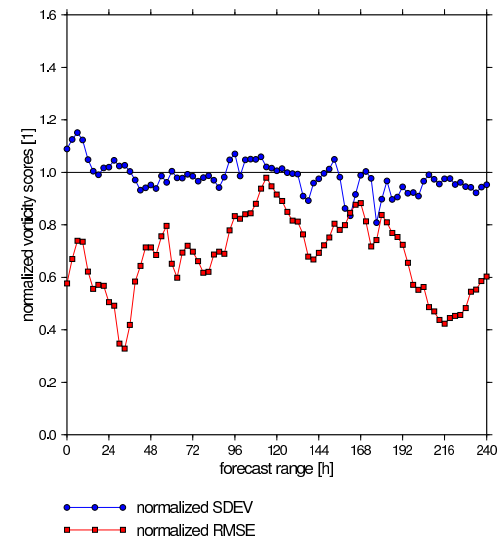
## Tests of Davies relaxation scheme



GMT 2006 Dec 7 09:38:41 E300-A00



GMT 2006 Dec 7 09:38:45 E300-A00



GMT 2006 Dec 7 09:38:50 E305-A000

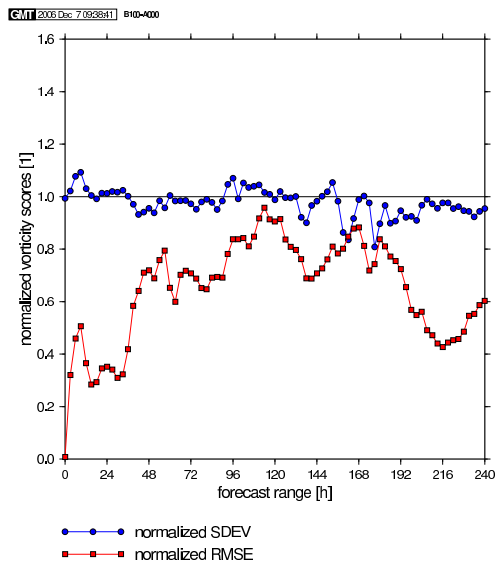
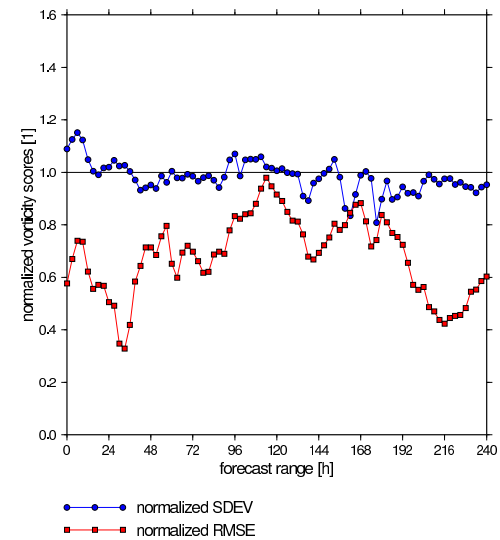
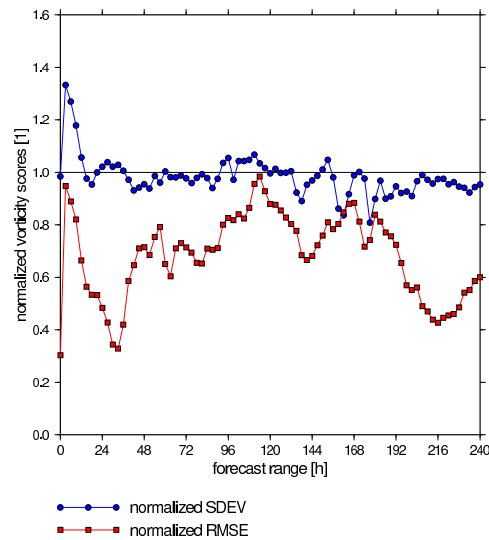
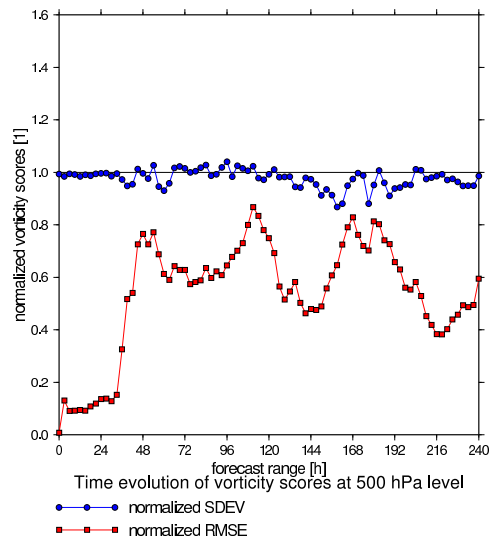
# Diagnostic tool for lat. coupling

Time evolution of vorticity scores at 500 hPa level

Time evolution of vorticity scores at 500 hPa level

Time evolution of vorticity scores at 500 hPa level

## Tests of Davies relaxation scheme



GMT 2005 Dec 7 09:38:54 E300-4000



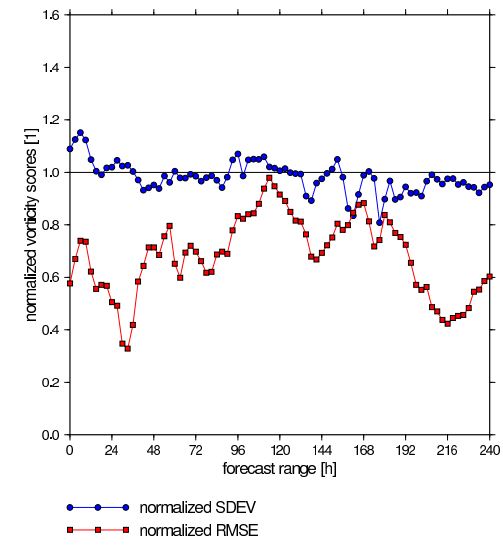
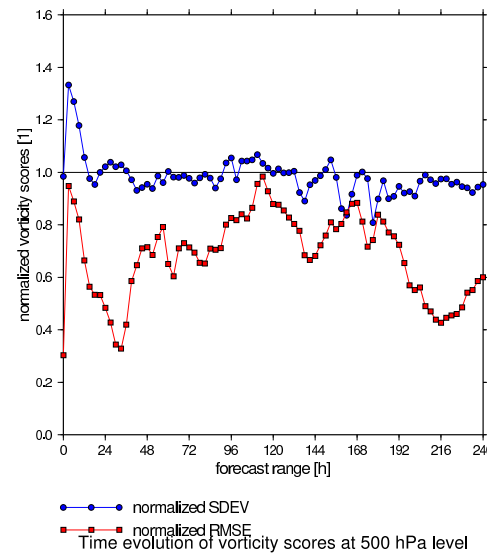
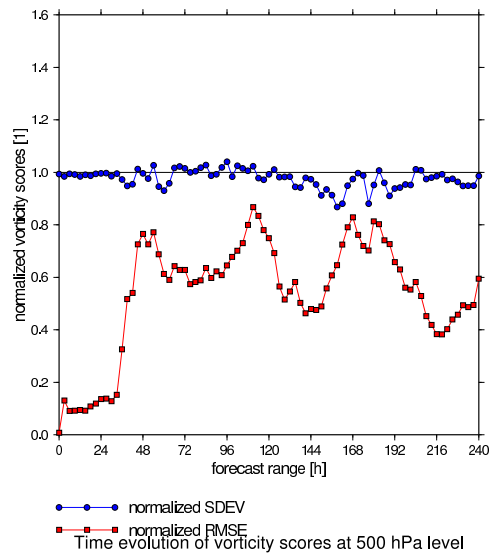
# Diagnostic tool for lat. coupling

Time evolution of vorticity scores at 500 hPa level

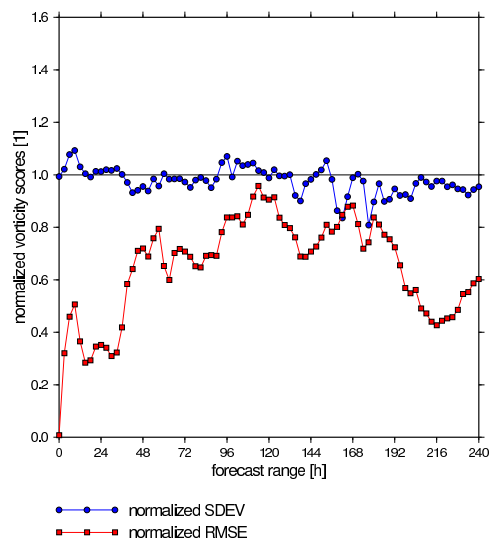
Time evolution of vorticity scores at 500 hPa level

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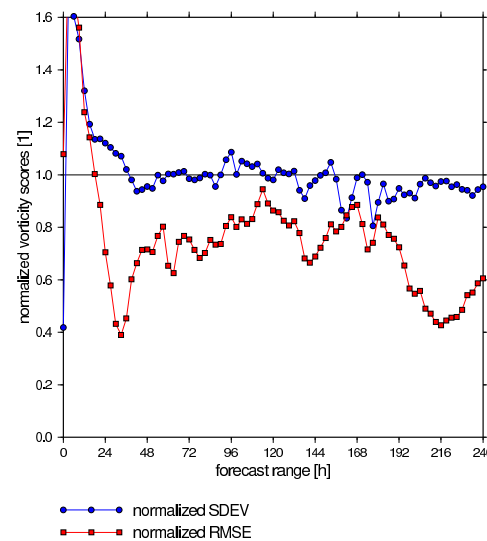
## Tests of Davies relaxation scheme



GMT 2006 Dec 7 09:38:41 E300-A00



GMT 2006 Dec 7 09:38:45 E300-A00

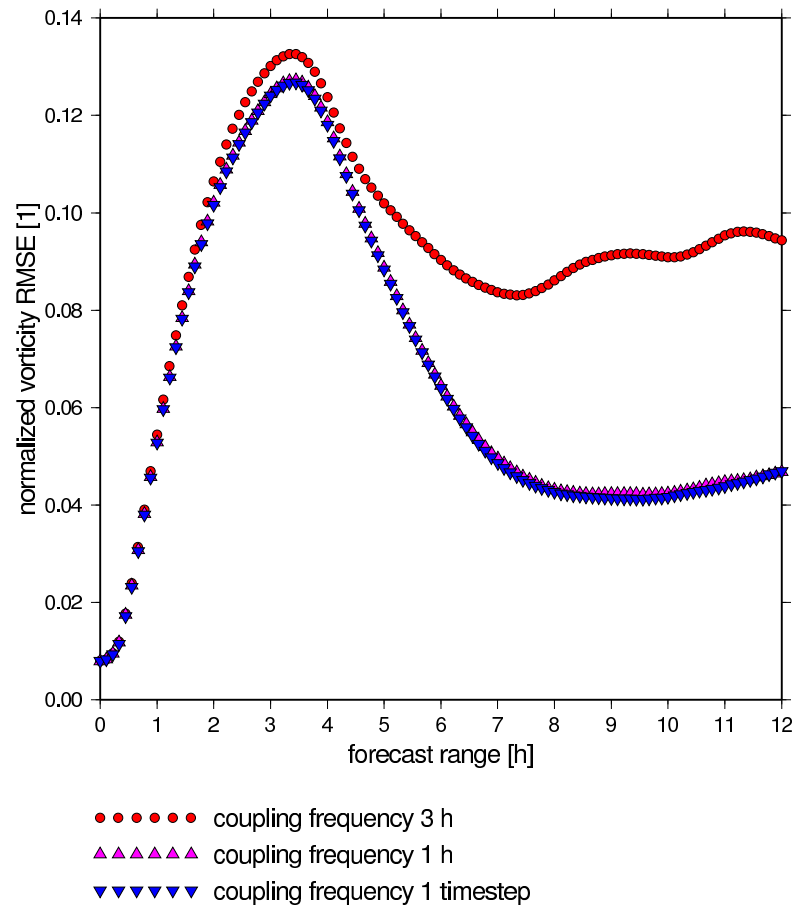


GMT 2006 Dec 7 09:38:50 E305-A00

# Diagnostic tool for lat. coupling

Time evolution of vorticity RMSE at 500 hPa level

## Sensitivity to coupling frequency



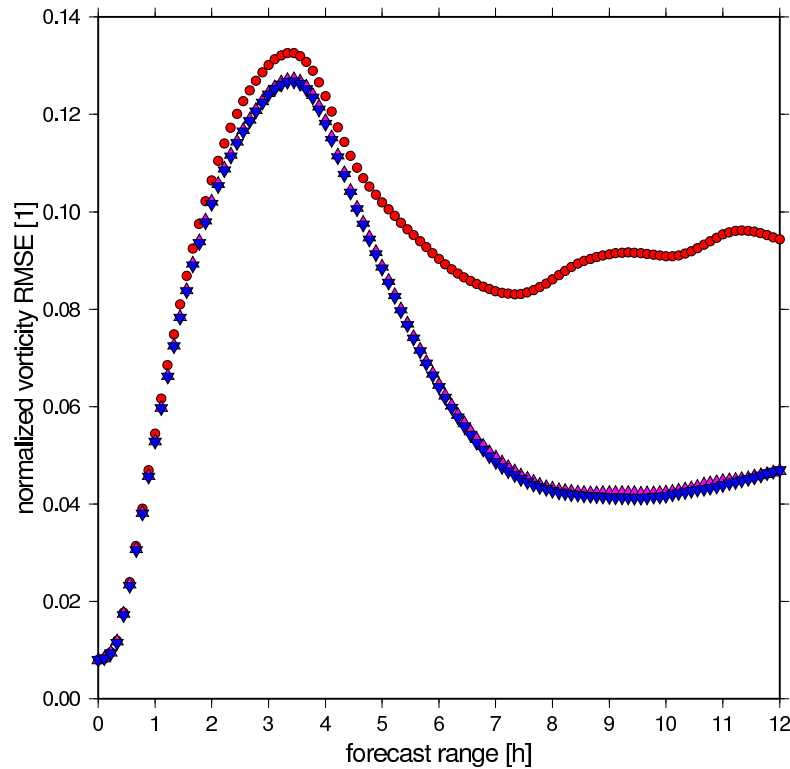
GMT 2006 Dec 7 10:45:29

# Diagnostic tool for lat. coupling

Time evolution of vorticity RMSE at 500 hPa level

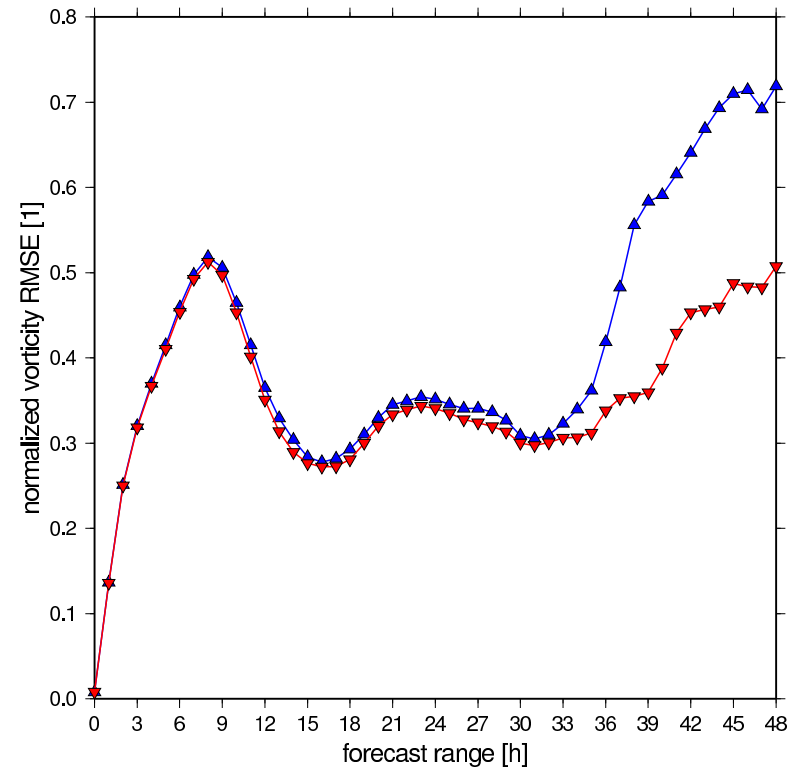
Time evolution of vorticity RMSE at 500 hPa level

## Sensitivity to coupling frequency



- coupling frequency 3 h
- ▲▲▲▲▲ coupling frequency 1 h
- ▼▼▼▼▼ coupling frequency 1 timestep

GMT 2006 Dec 7 10:45:29



- ▲▲▲▲▲ coupling frequency 3 h
- ▼▼▼▼▼ coupling frequency 1 h
- ▲▲▲▲▲ coupling frequency 1 timestep

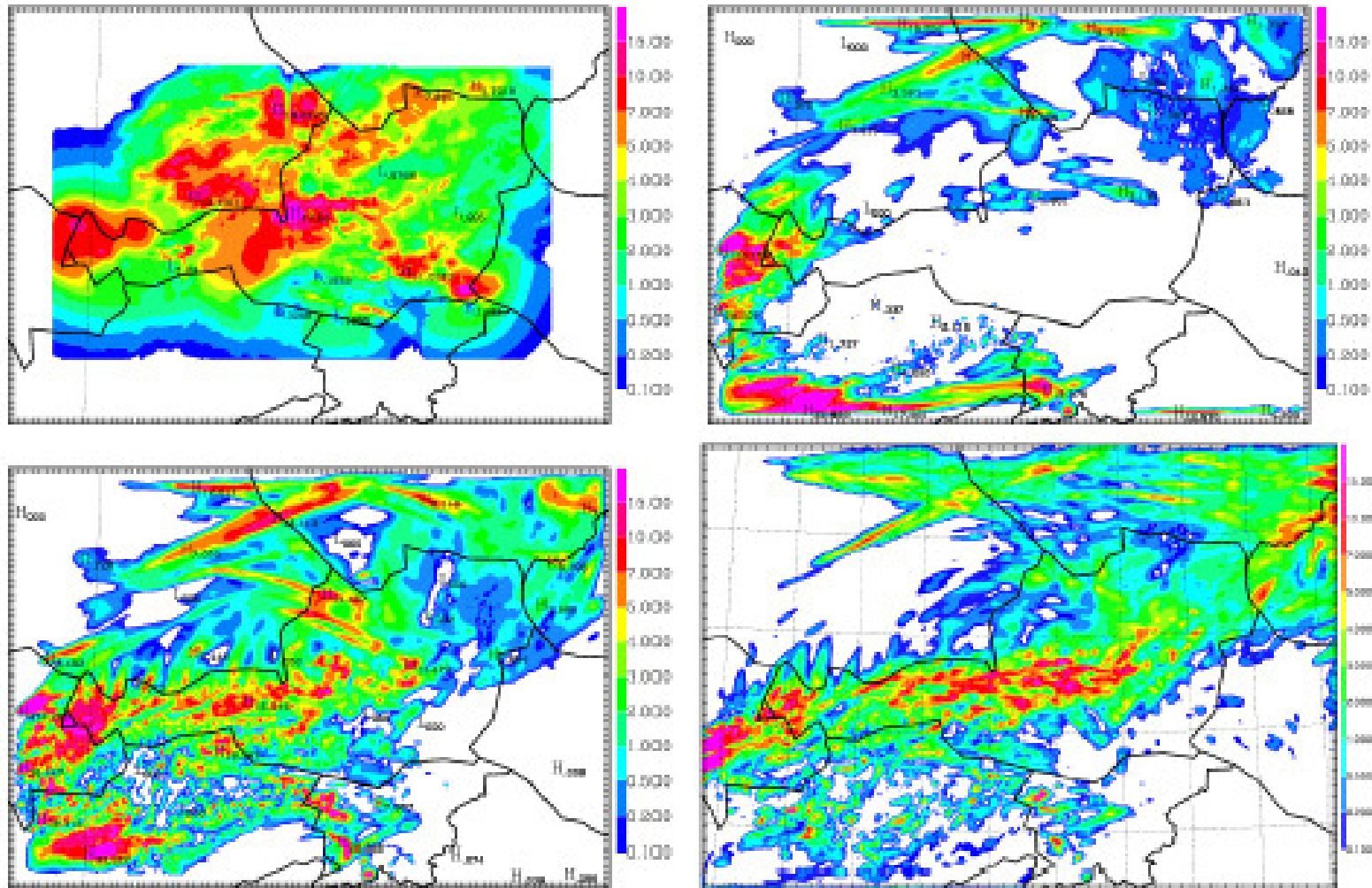
GMT 2006 Dec 7 12:54:32

# Plan for 2007

Project	Topic	Planned effort	LACE support	
I.	VFE	7.5	2	
II.	SLHD above orography	1.5		
	RUBC	1.5		
	New interpolators for SL	4		2
	Phys. coupling to dynamics	2		1
	TL/AD of plane SL	1		
	TL/AD of SLHD	3.5		
	Thermodynamic consistency	2		
III.	Alternative LBC formulation	2		
	Spectral coupling	2		
	<i>Total:</i>	<b>27</b>	<b>5</b>	

# SLHD above orography

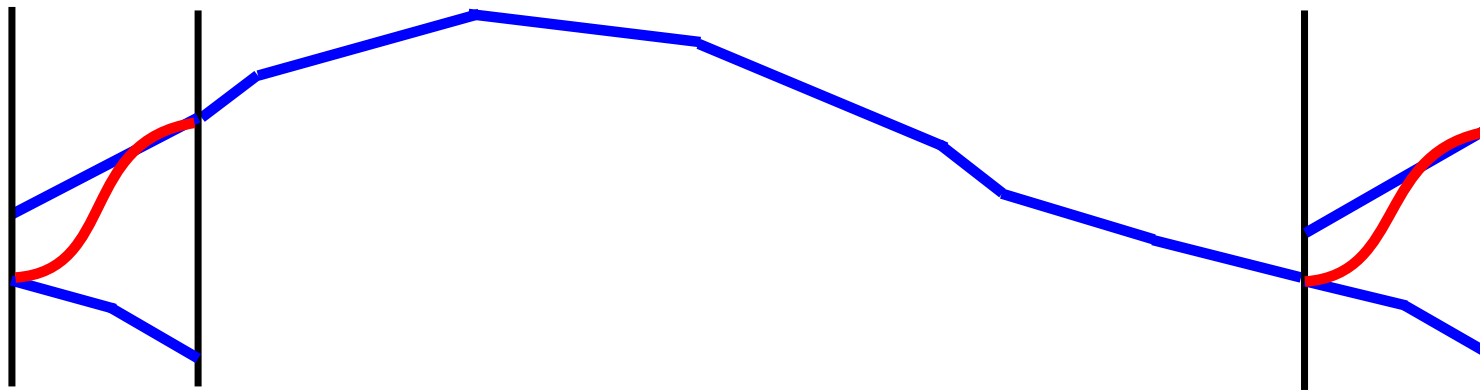
24h accumulated precipitation over Austria for the 23/06/2006



# Alternative formulation of LBC

## Ingredients:

- Boyd (2005)



# Alternative formulation of LBC

## Ingredients:

- Boyd (2005)
- SL advection

# Alternative formulation of LBC

## Ingredients:

- Boyd (2005)
- SL advection
- SLHD



# Alternative formulation of LBC

