

# The Semi-Lagrangian Horizontal Diffusion Scheme

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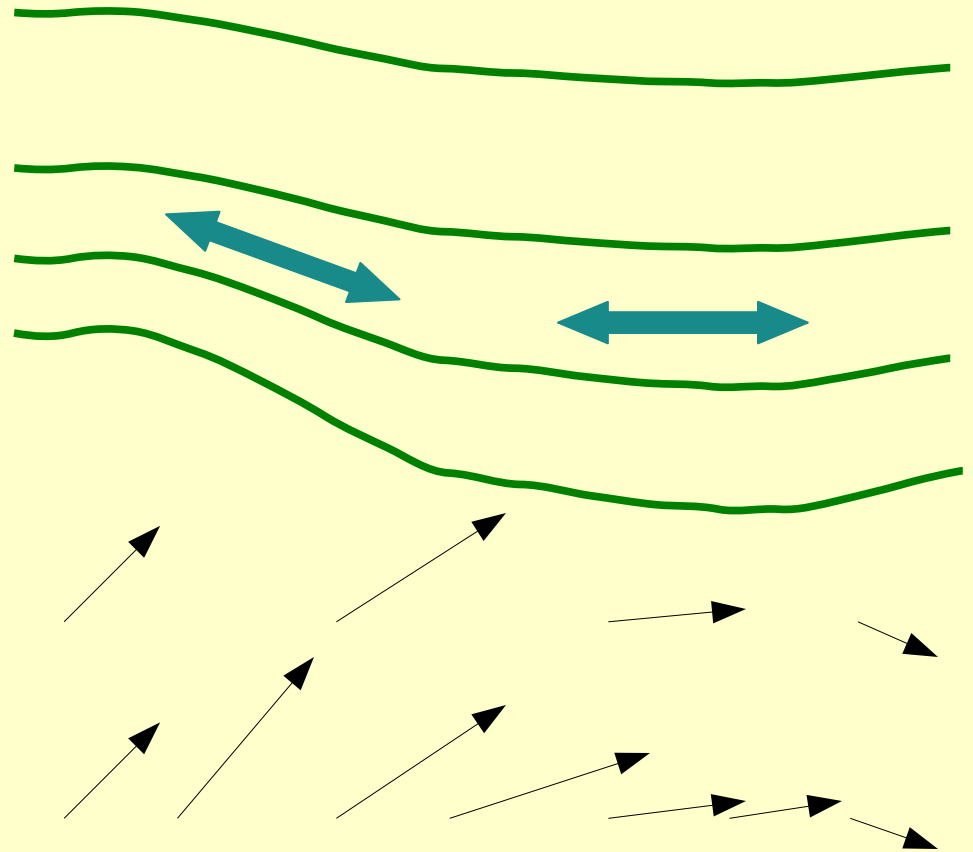
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# Outline

- 4<sup>th</sup> order numerical diffusion and semi-lagrangian horizontal diffusion
- Case studies in 8 km resolution
  - Upper level cyclone
  - Twin cyclones
  - Fog in anticyclone
- Case studies in 2 km resolution
  - severe and mild bura
- Summary

# Numerical diffusion

- acts as a numerical filter
- applied along model level that follows orography - not purely horizontal
- no dependence on horizontal wind shear
- to parameterize physical process of turbulent diffusion in horizontal non-linear operator depending on flow characteristics is needed



# SLHD

Semi-Lagrangian advection

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

Discretised in 3TL:

$$\frac{\Psi(\vec{x}, t + \Delta t) - \Psi(\vec{x} - 2\vec{\alpha}, t - \Delta t)}{2\Delta t} = \frac{1}{2} [\mathcal{R}(\vec{x} - 2\vec{\alpha}, t) + \mathcal{R}(\vec{x}, t)] + \mathcal{F}(\vec{x} - 2\vec{\alpha}, t - \Delta t)$$

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

# SLHD (2)

- stronger horizontal shear
- bigger deformation
- more weight to the smoother
- stronger horizontal diffusion

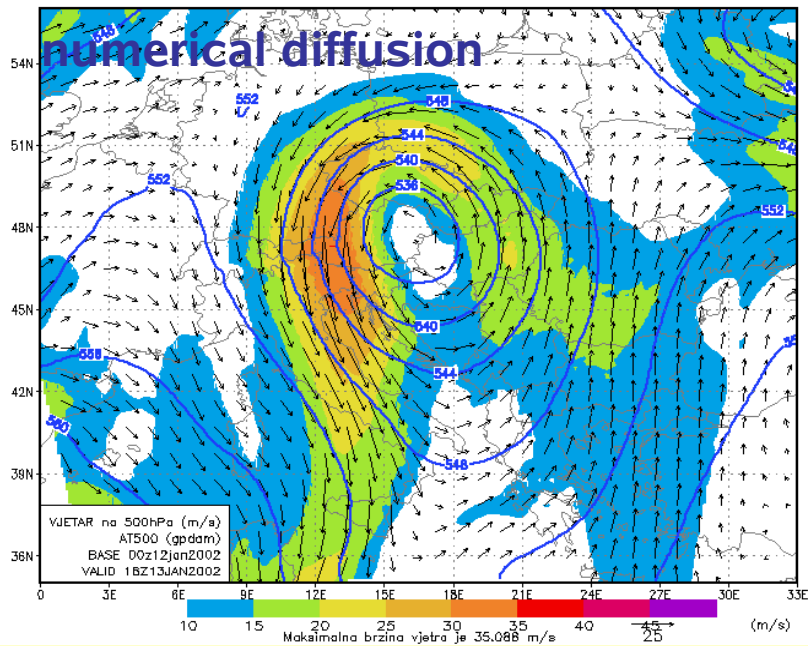
$$I = (1 - \kappa)I_A + \kappa I_D = I_A + \kappa(I_D - I_A)$$

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

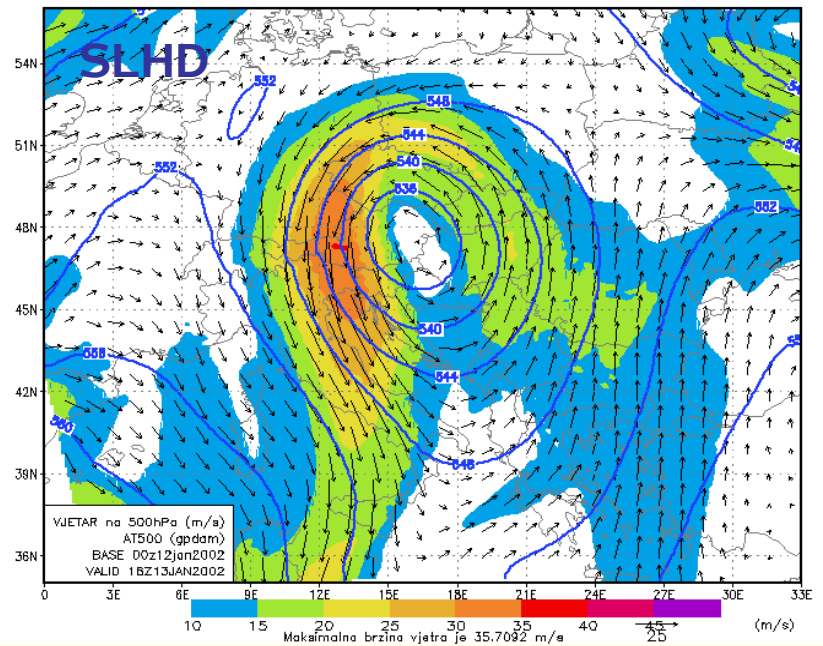
$$\kappa = \frac{F(d)\Delta t}{1 + F(d)\Delta t}$$

$$F(d) = \left(\frac{\Delta h_{ref}}{\Delta h}\right)^P \cdot a \left[\max\left(1, \frac{d}{d_0}\right)\right]^b d$$

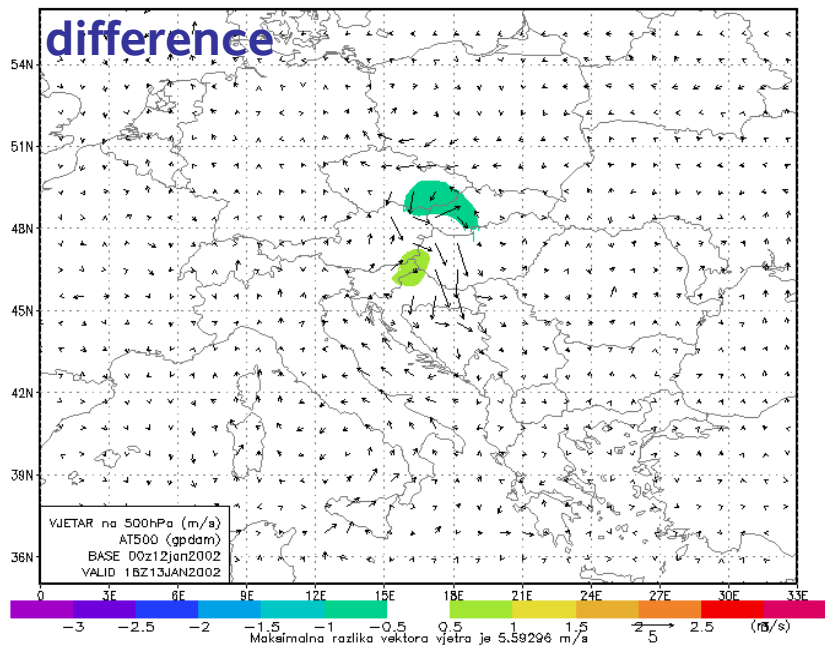
ALADIN/LACE VJETAR + Z na 500hPa u 18Z13JAN2002 UTC 42h forecast



Novi ALADIN/LACE VJETAR + Z na 500hPa u 18Z13JAN2002 UTC 42h forecast

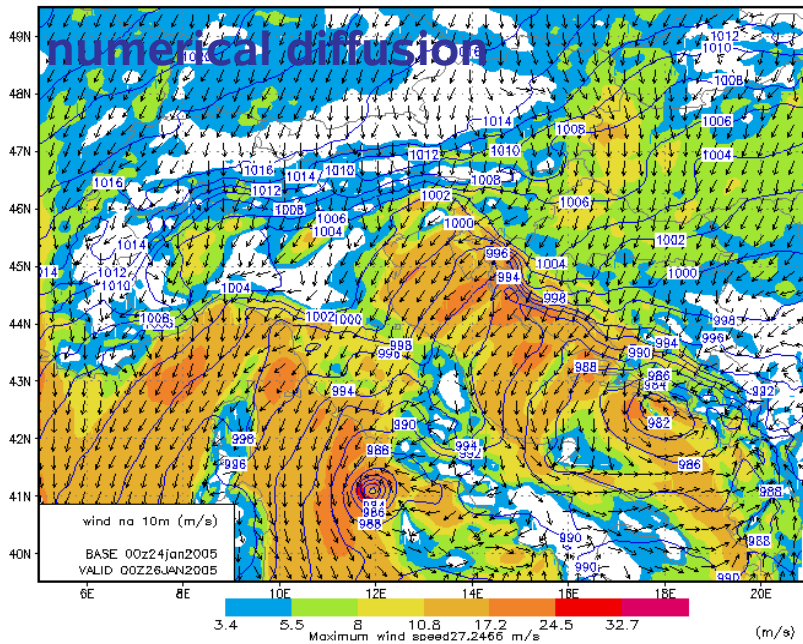


ALADIN/LACE VJETAR + Z na 500hPa u 18Z13JAN2002 UTC 42h forecast

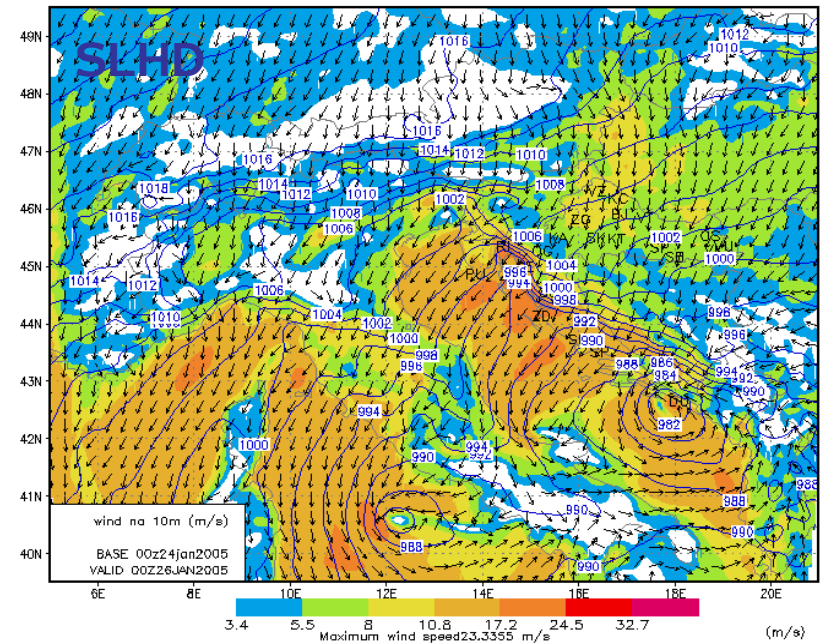


AT500 and wind obtained with numerical diffusion (top left), SLHD (top) and their difference (left), 42 hour forecast starting from 00 UTC 12th January 2002.

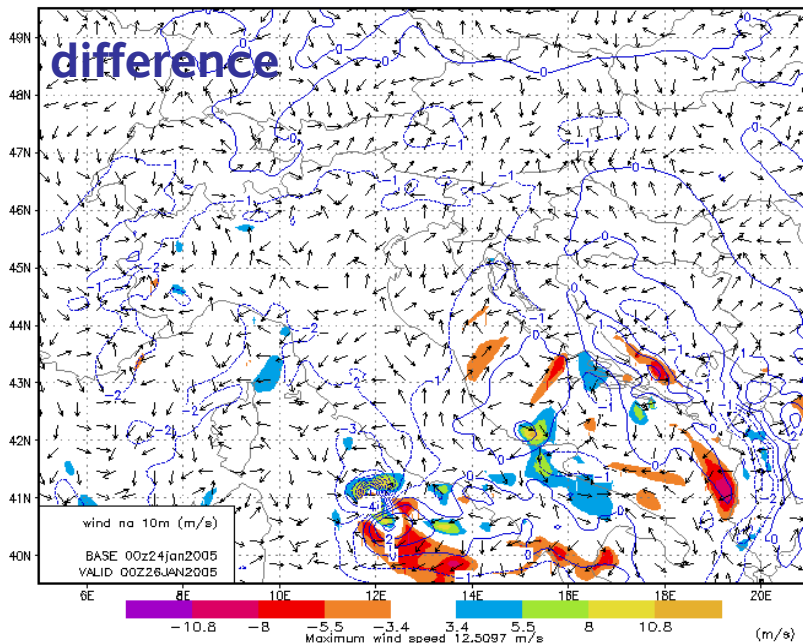
ALADIN/HR wind 00Z26JAN2005 UTC 48h forecast



New ALADIN/HR wind 00Z26JAN2005 UTC 48h forecast

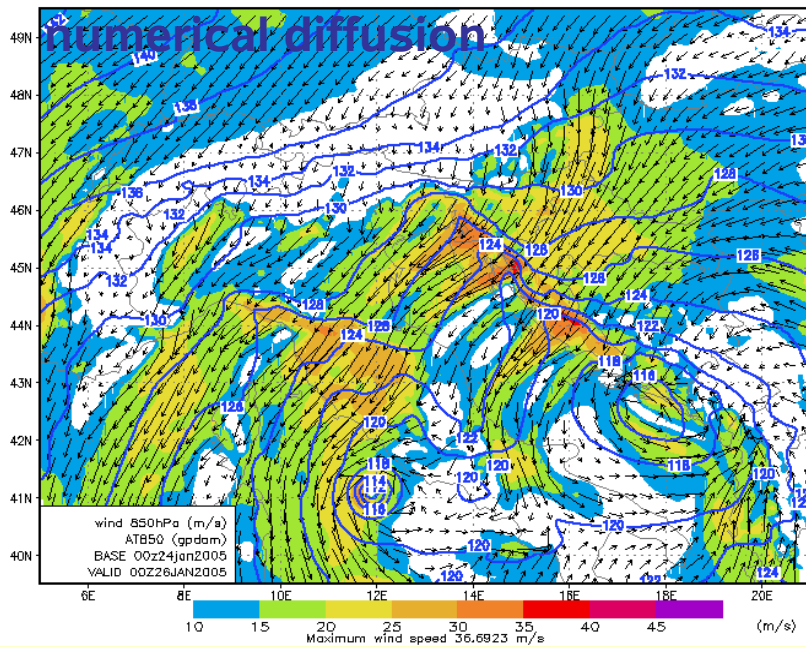


Difference ALADIN/HR wind 00Z26JAN2005 UTC 48h forecast

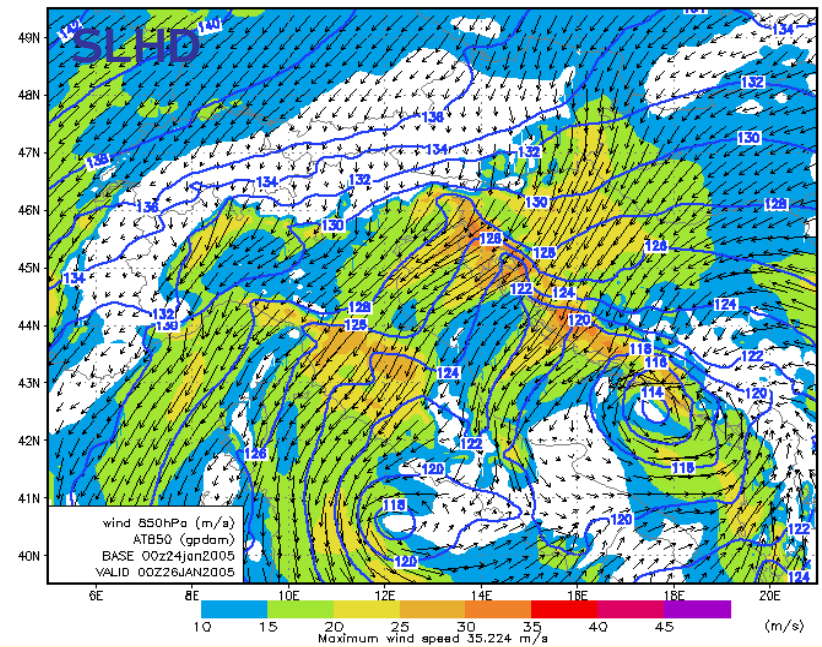


10m wind and mean sea level pressure obtained with numerical diffusion (top left), SLHD (top) and their difference (left), 48 hour forecast starting from 00 UTC 24th January 2005.

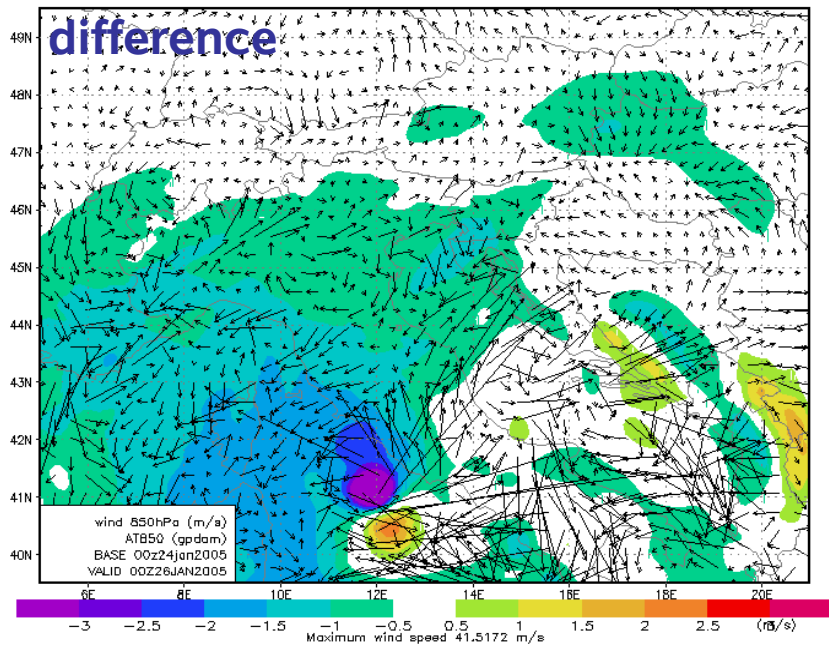
ALADIN/HRn8 wind + Z 850hPa 00Z26JAN2005 UTC 48h forecast



New ALADIN/HRn8 wind + Z 850hPa 00Z26JAN2005 UTC 48h forecast

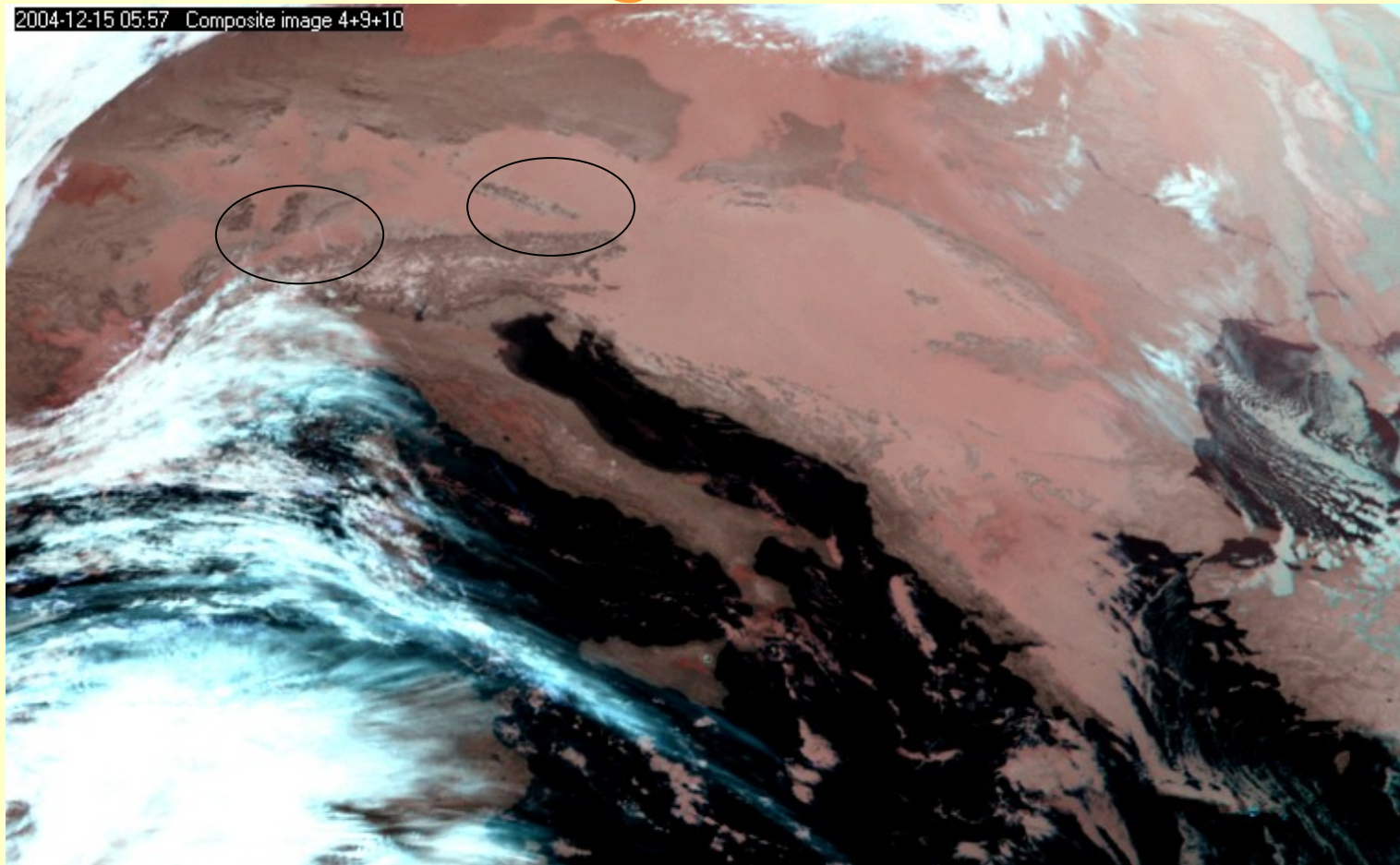


Difference ALADIN/HR wind + Z 850hPa u 00Z26JAN2005 UTC 48h forecast



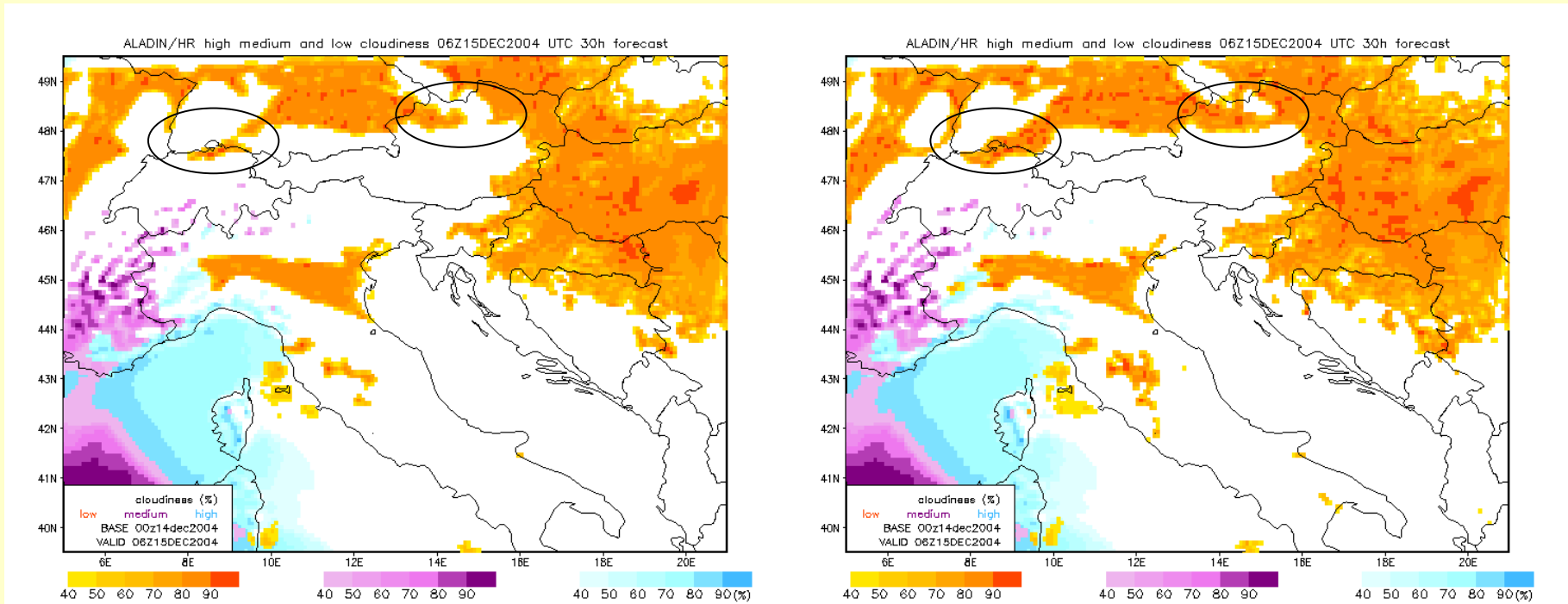
AT850 and wind obtained with numerical diffusion (top left), SLHD (top) and their difference (left), 48 hour forecast starting from 00 UTC 24th January 2005.

# Fog case



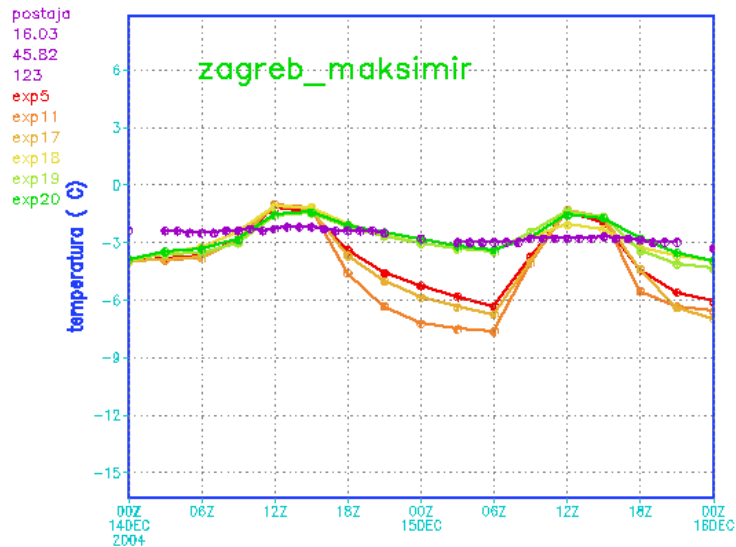
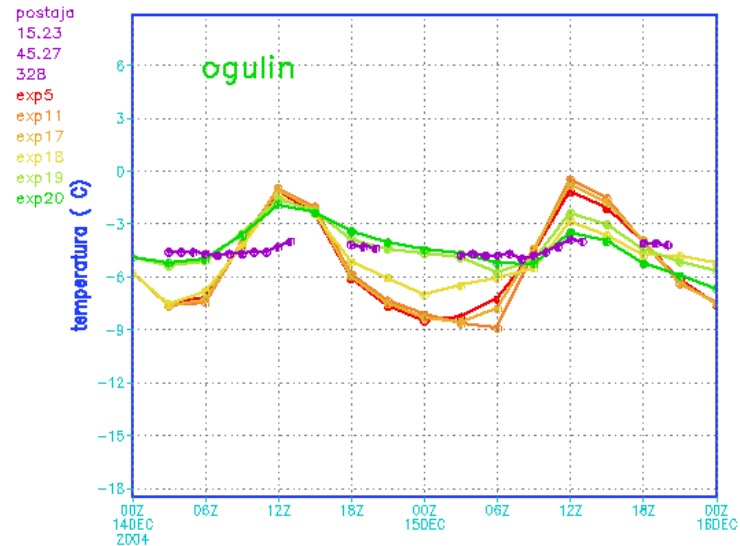
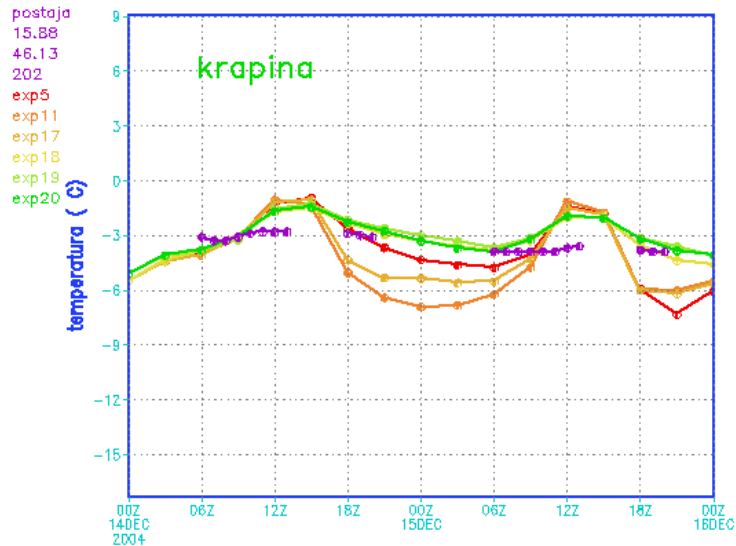
- Meteosat-8 RBG composite of channels 3.9, 10.8 and 12.0  $\mu\text{m}$  for December 15th 2004, 06 UTC.

# Fog case



- Low, medium and high cloudiness, numerical diffusion (left) and SLHD (right), 30 hour forecast starting from 00 UTC 14th December 2004.

# Comparison to data



Comparison of the modelled 2m temperature evolution for 00 UTC run on 14th December 2004 measured data from synoptic station

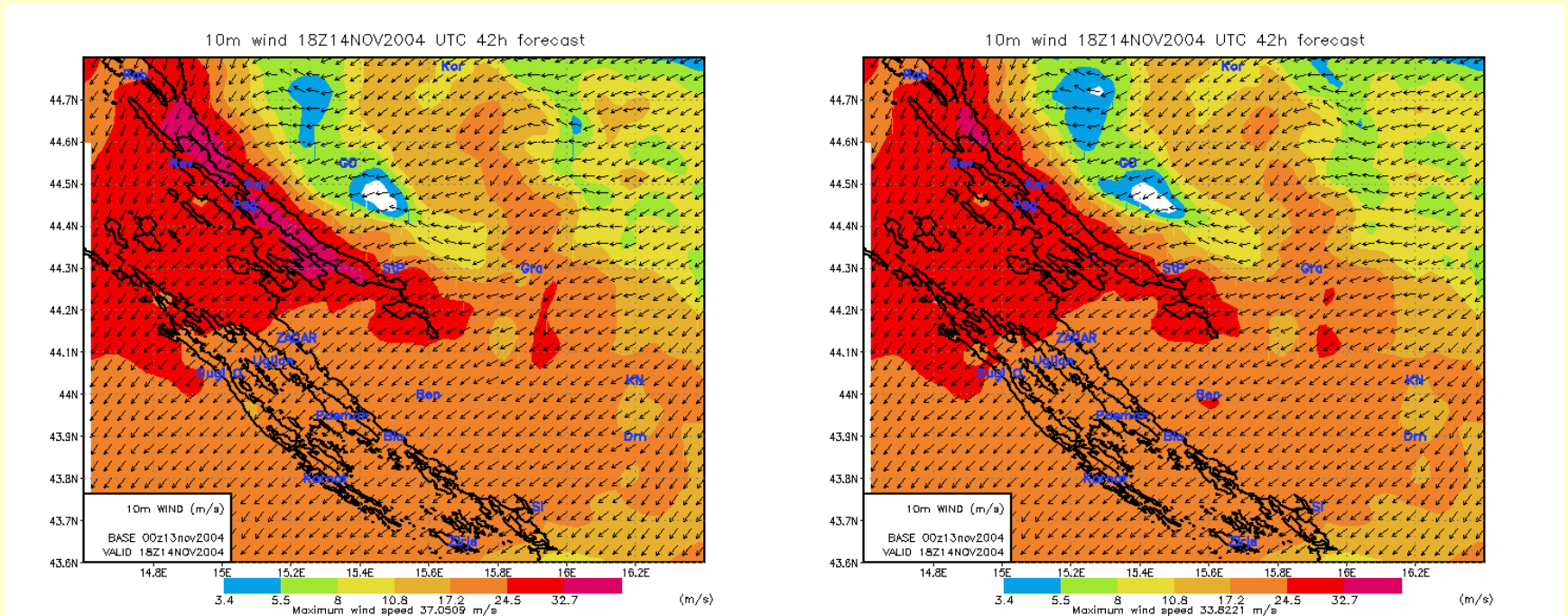
sk, 12-16 June 2006

reference  
NER  
LRAUTOEV  
SLHD  
mean orog  
SLHD+m.o.

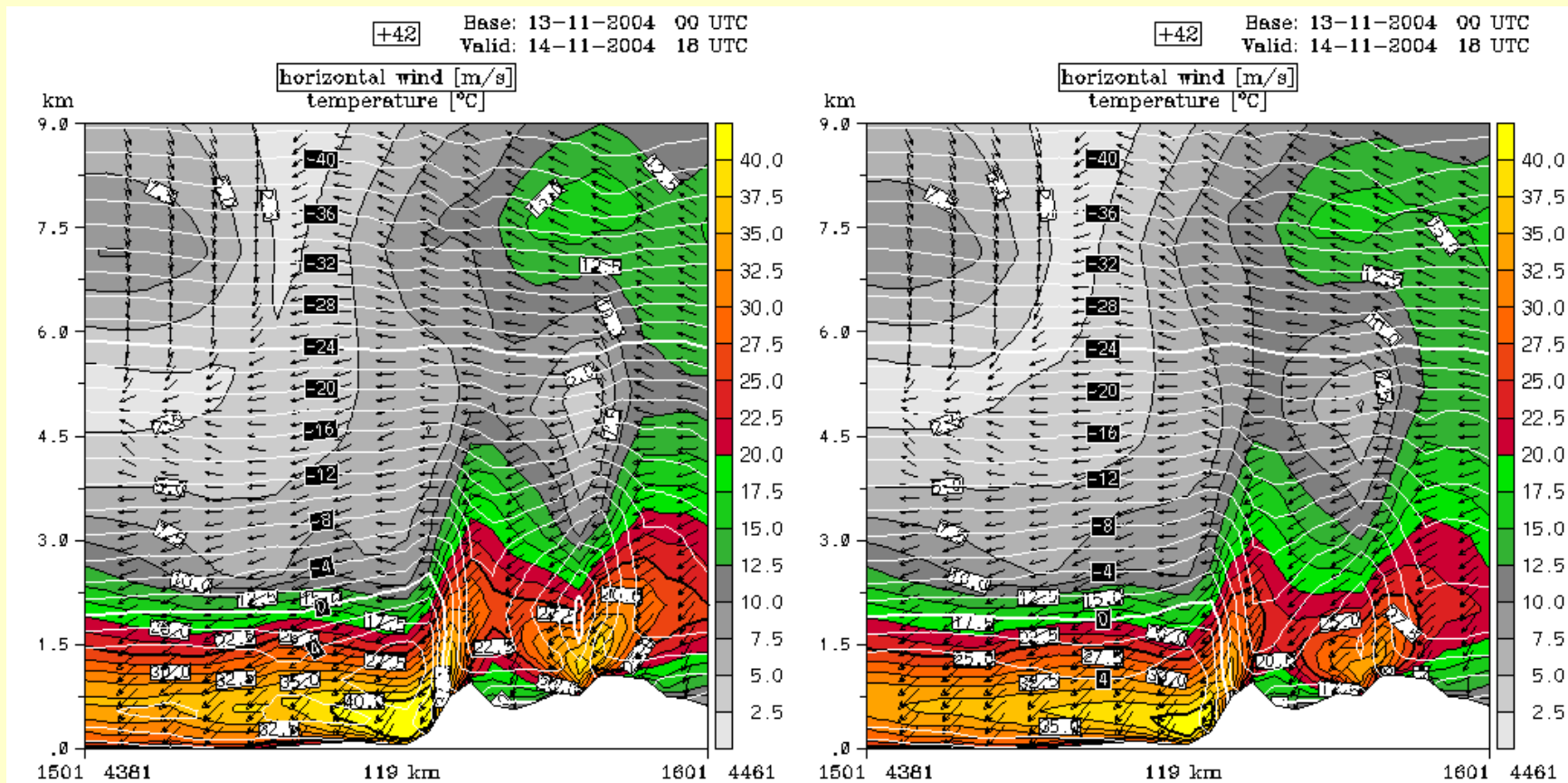
# High resolution cases

- two cases of bura:
- 
- 14<sup>th</sup> November 2004, severe bura
- 4<sup>th</sup> November 2003: very weak and localized in the area close to the town of Senj

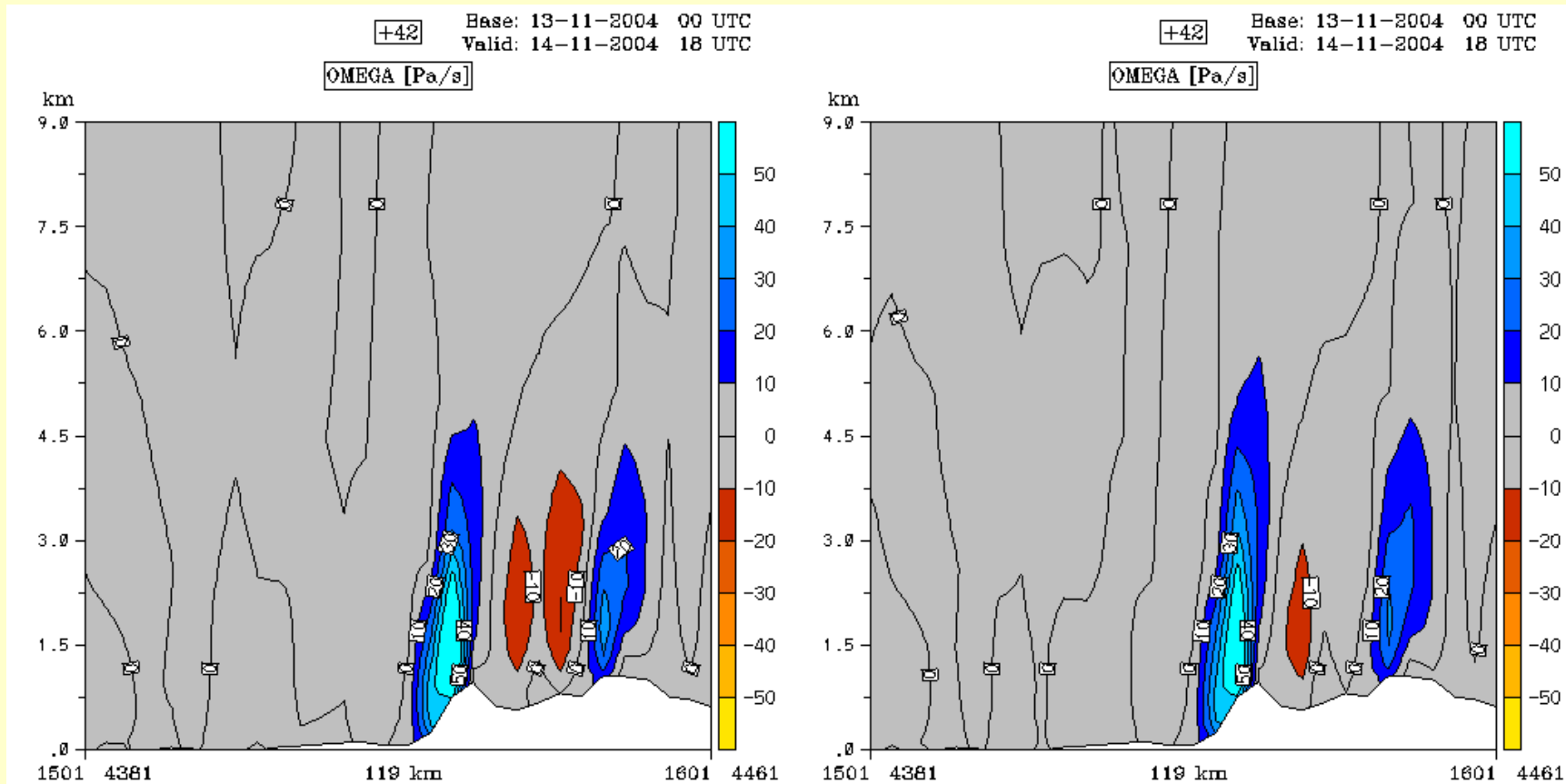
# » 14<sup>th</sup> November 2004



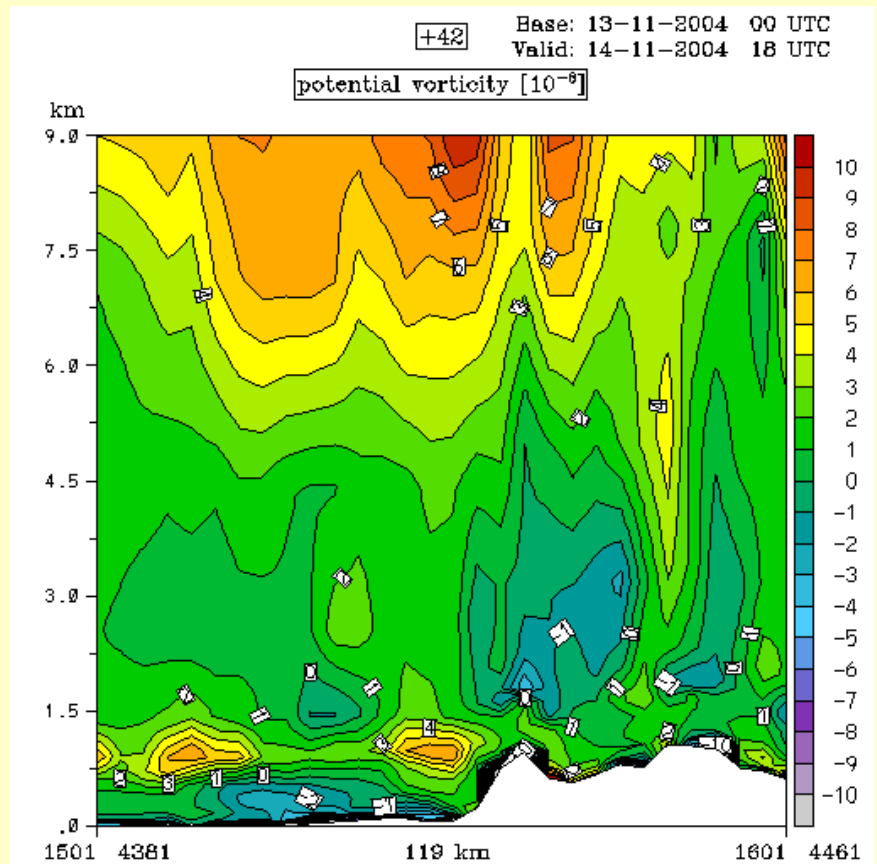
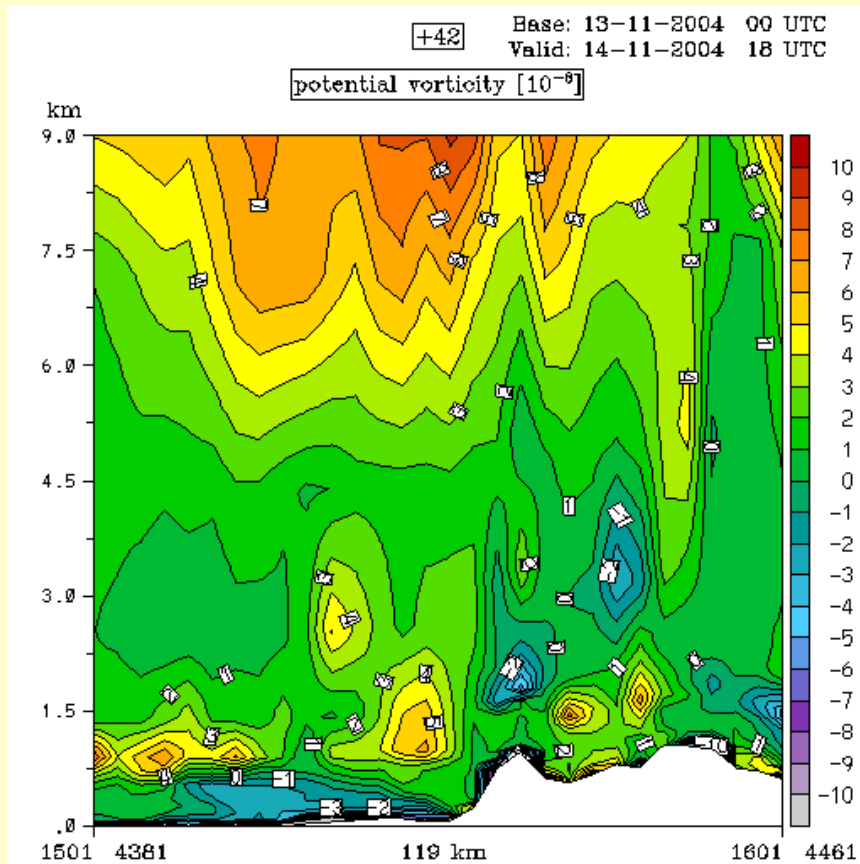
- 10m wind, numerical diffusion (left) and SLHD (right)
- 42 hour forecast starting 00 UTC 13<sup>th</sup> November 2004
- maslenica domain



- vertical cross-section of horizontal wind
- 42 hour forecast starting 00 UTC 13<sup>th</sup> November 2004
- numerical diffusion (left) and SLHD (right)

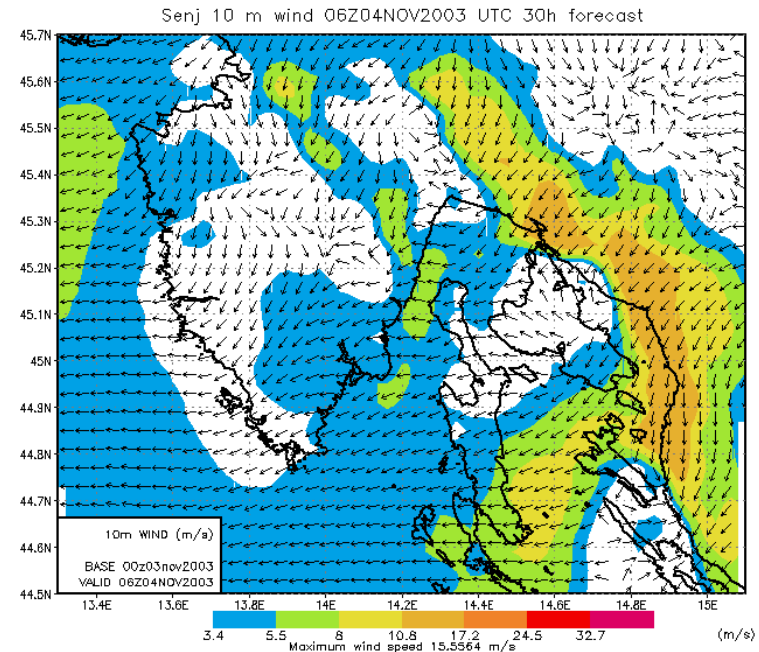
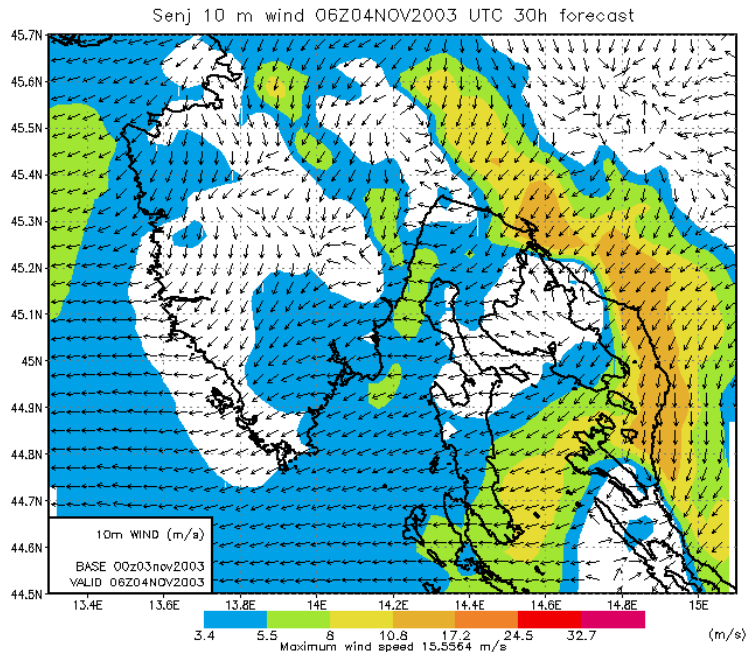


- vertical cross-section of vertical wind speed (omega)
- 42 hour forecast starting 00 UTC 13<sup>th</sup> November 2004
- numerical diffusion (left) and SLHD (right)

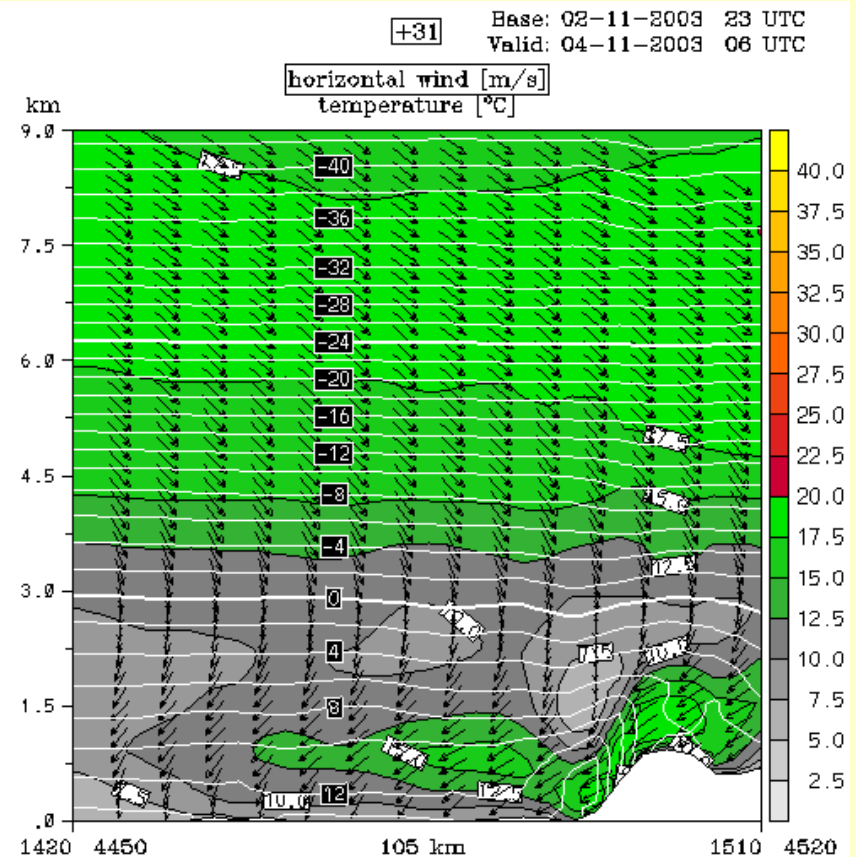
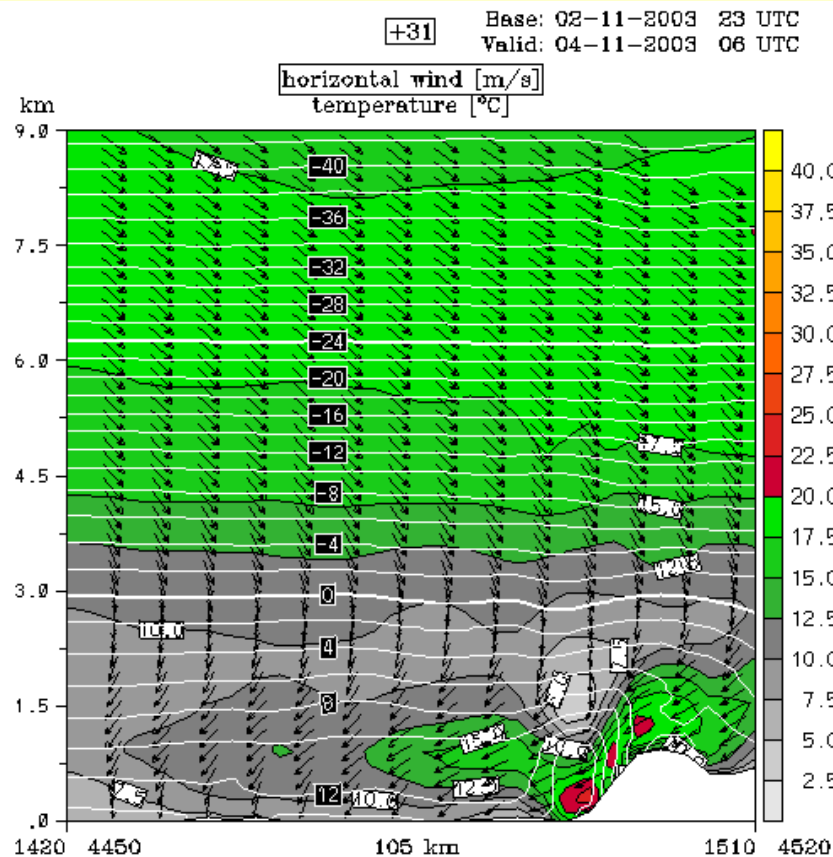


- vertical cross-section of vertical potential vorticity
- 42 hour forecast starting 00 UTC 13<sup>th</sup> November 2004
- numerical diffusion (left) and SLHD (right)

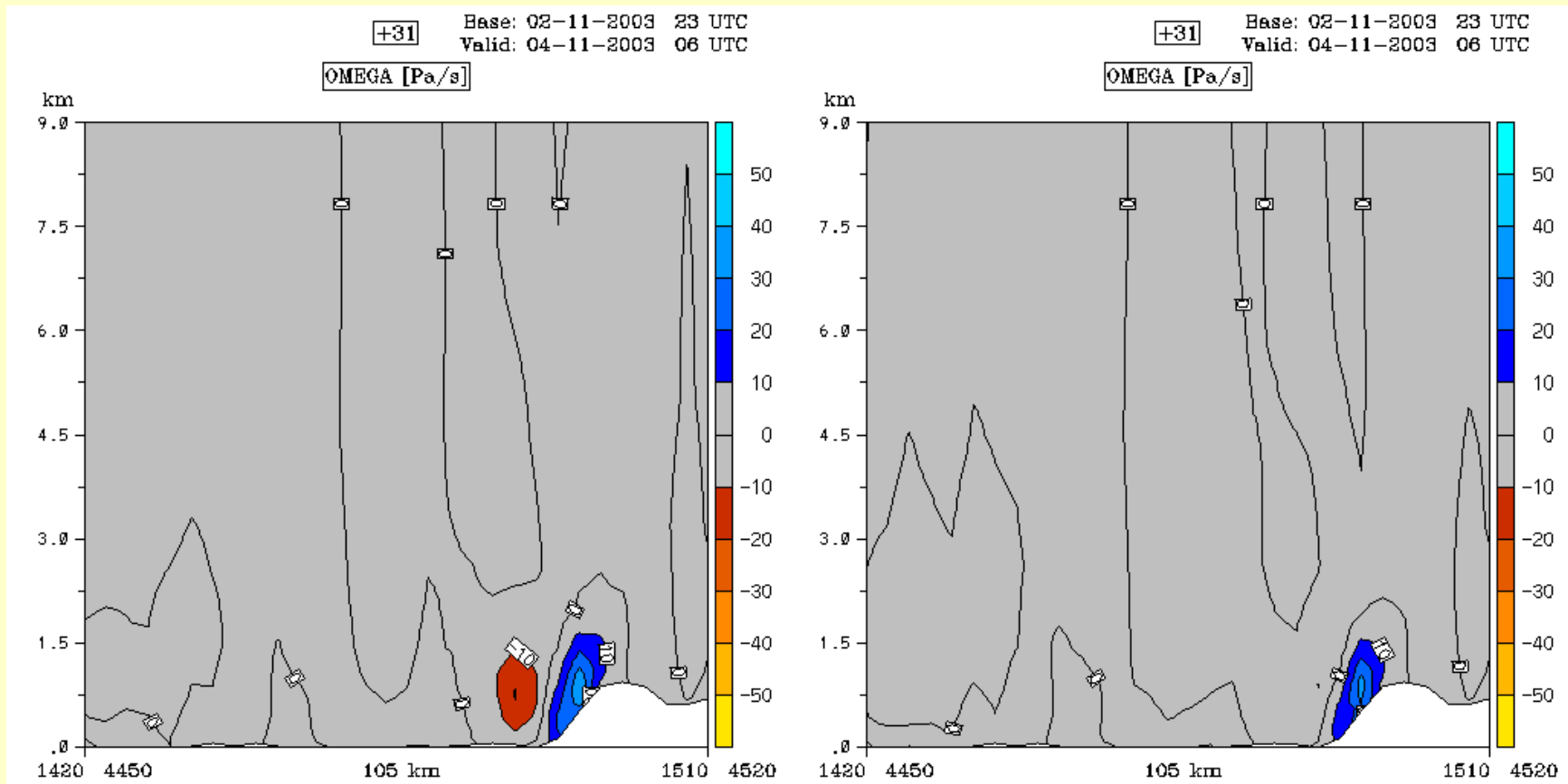
# 4<sup>th</sup> November 2003



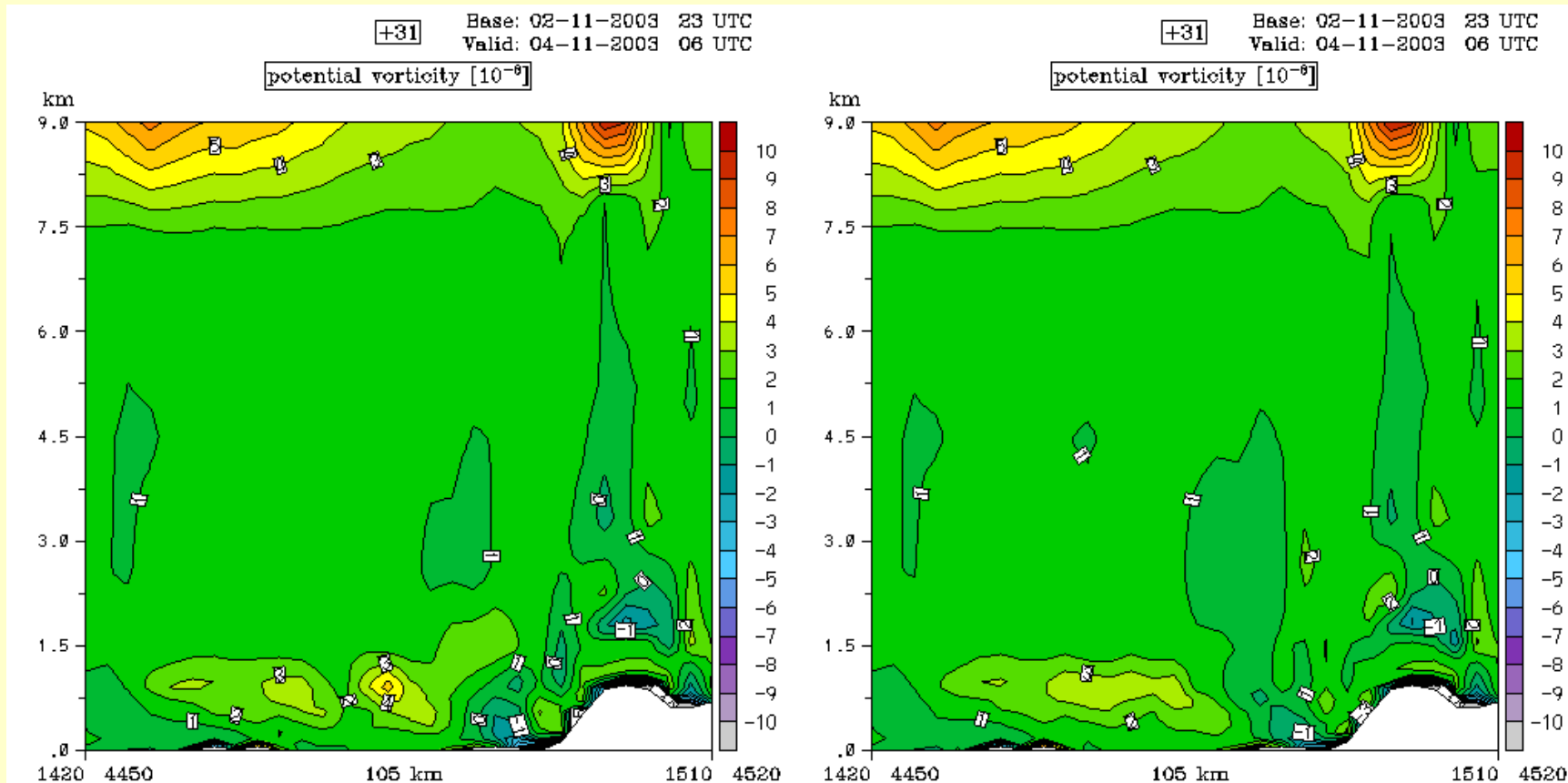
- 10m wind, numerical diffusion (left) and SLHD (right)
- 30 hour forecast starting 00 UTC 3<sup>rd</sup> November 2003
- Senj domain



- vertical cross-section of horizontal wind
- 30 hour forecast starting 00 UTC 3<sup>rd</sup> November 2003
- numerical diffusion (left) and SLHD (right)



- vertical cross-section of vertical wind speed (omega)
- 30 hour forecast starting 00 UTC 3<sup>rd</sup> November 2003
- numerical diffusion (left) and SLHD (right)



- vertical cross-section of vertical potential vorticity
- 30 hour forecast starting 00 UTC 3<sup>rd</sup> November 2003
- numerical diffusion (left) and SLHD (right)

# Summary

- Semi-Lagrangian Horizontal Diffusion (SLHD) shows beneficial impact on the
  - reduction of the overestimated cyclone intensity,
  - correction of cyclone position while not altering a good intensity prediction,
  - improvement of fog forecast in the valleys in an anticyclone