The Semi-Lagrangian Horizontal Diffusion Scheme

Martina Tudor and Filip Vana[2]

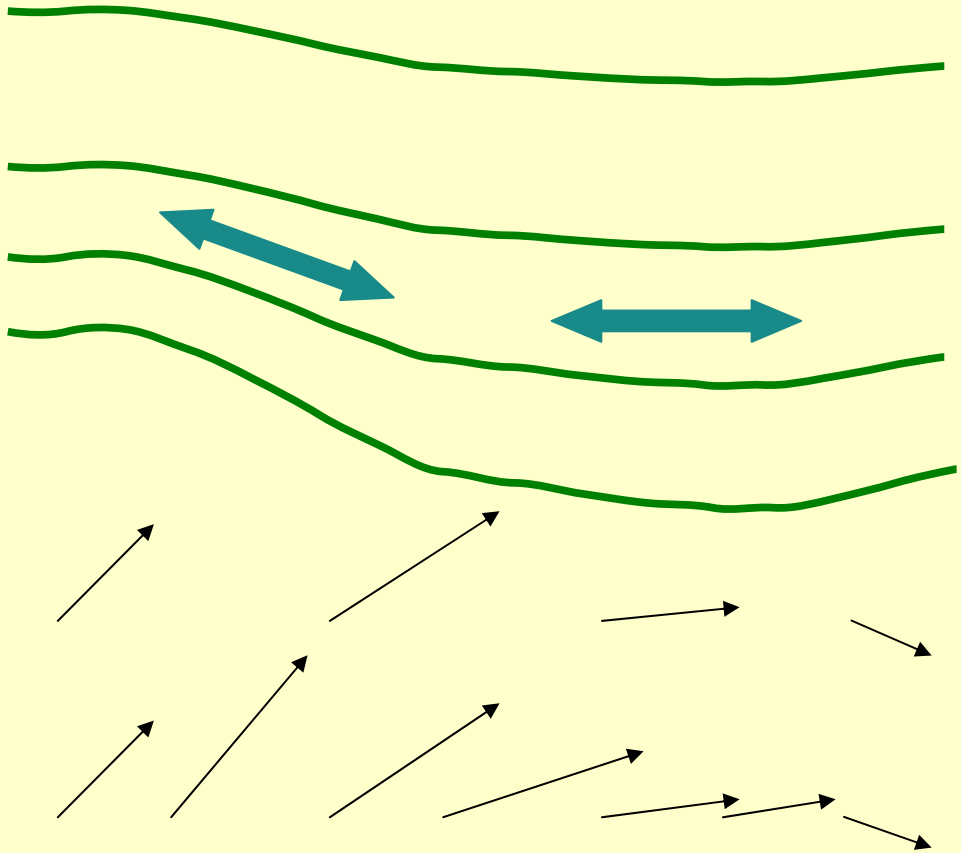
[1] Meteorological and Hydrological Service, Grič 3, Zagreb, Croatia
[2] Czech Hydrometeorological Institute, Na Šabatce 16, Prague, Czech Republic

Outline

- 4^{th} order numercal 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 ho 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:

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

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

SLHD (2)

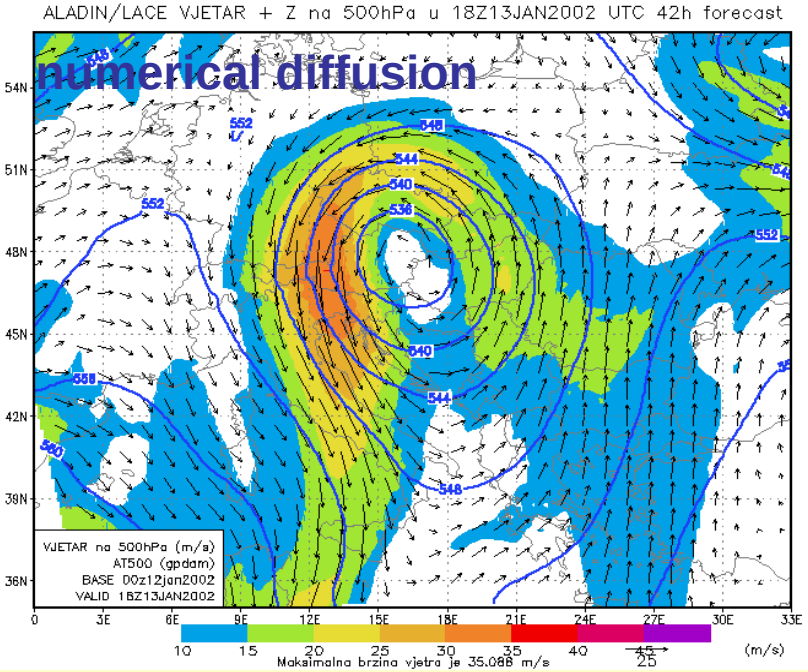
- stronger horizontal shear
- bigger deformation
- more weight to the smoother
- stronger horizontal diffusion

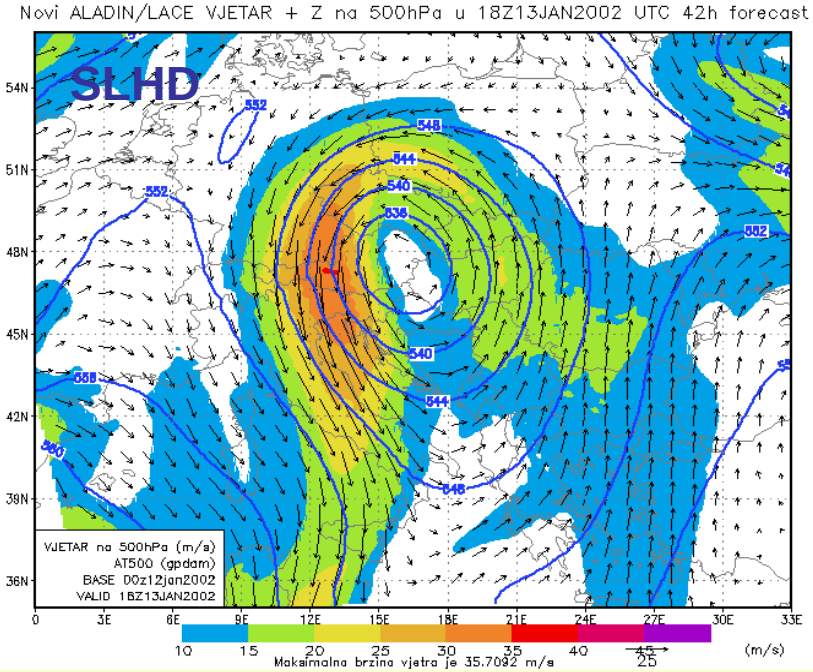
$$I = (1-\kappa)I_A + \kappa I_D = I_A + \kappa(I_D - I_A)$$

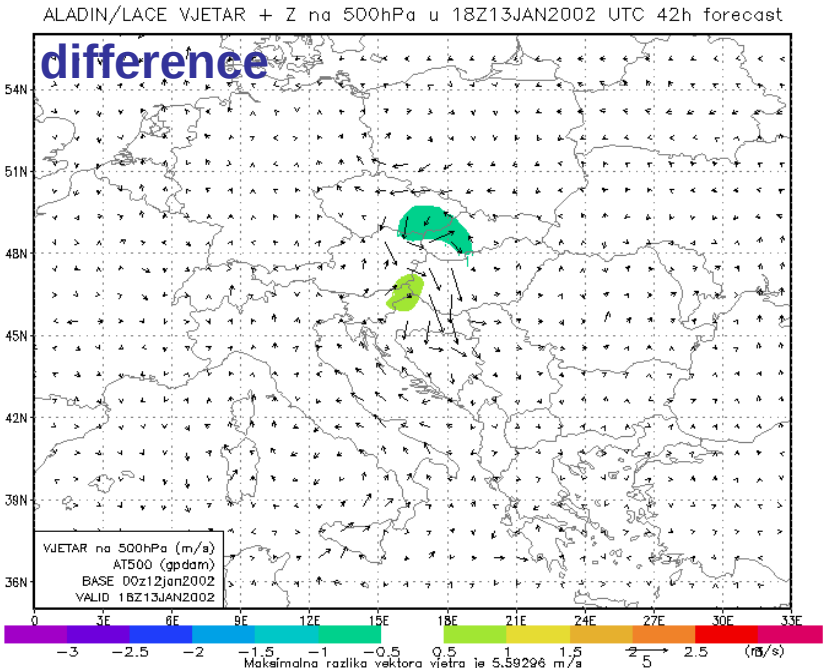
$$\kappa \propto d = \sqrt{\left(\underbrace{\frac{\partial u}{\partial x} - \frac{\partial v}{\partial y}}_{d_T}\right)^2 + \left(\underbrace{\frac{\partial u}{\partial y} + \frac{\partial v}{\partial x}}_{d_S}\right)^2}$$

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

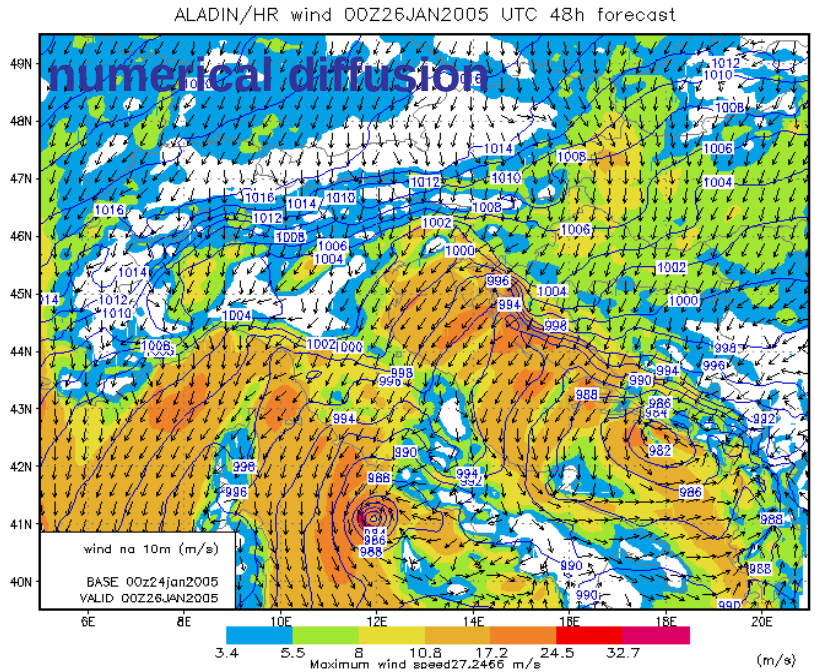
$$F(d) = \left(\frac{\Delta h_{ref}}{\Delta h}\right)^P \cdot a\left[\max(1, \frac{d}{d_0})\right]^b d$$

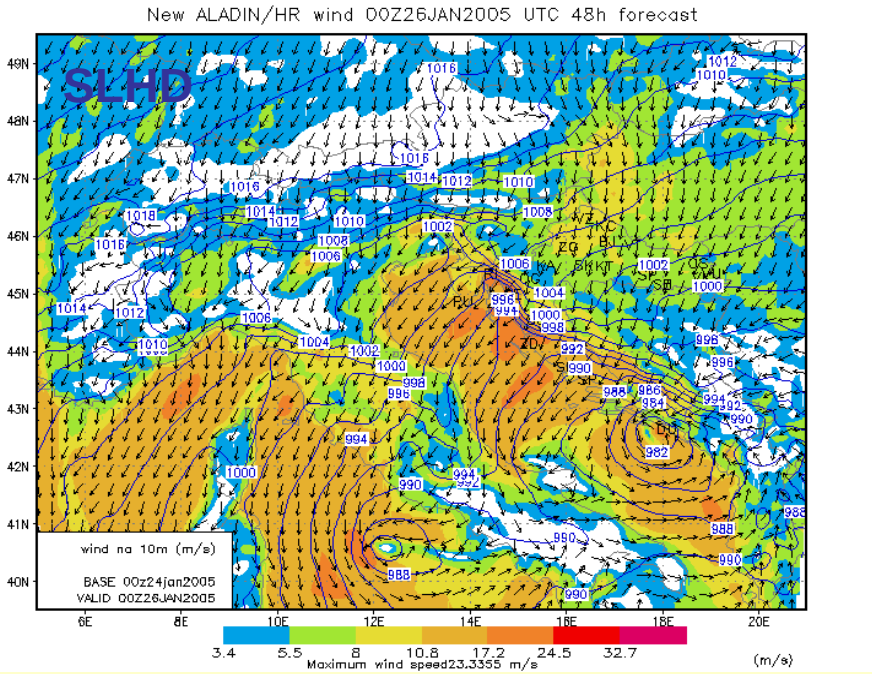


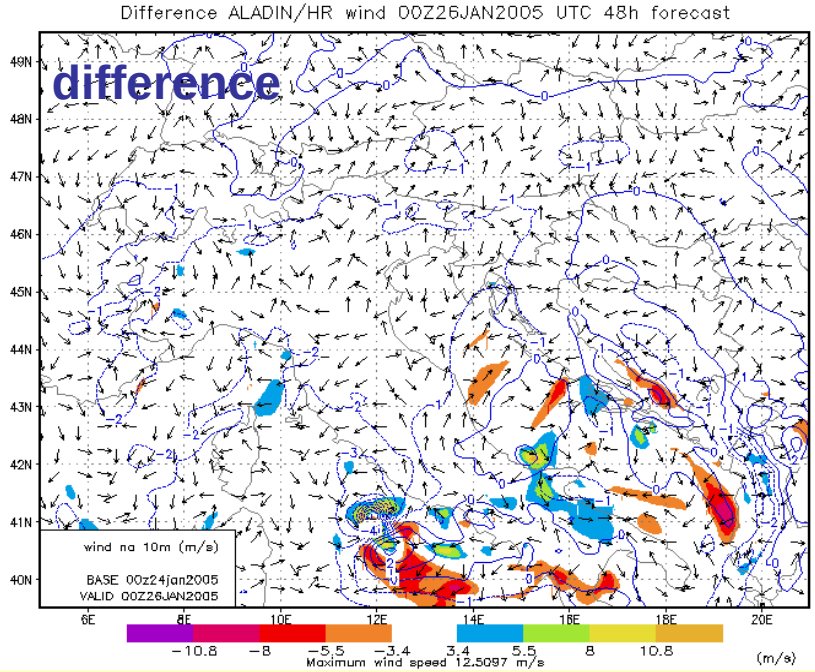




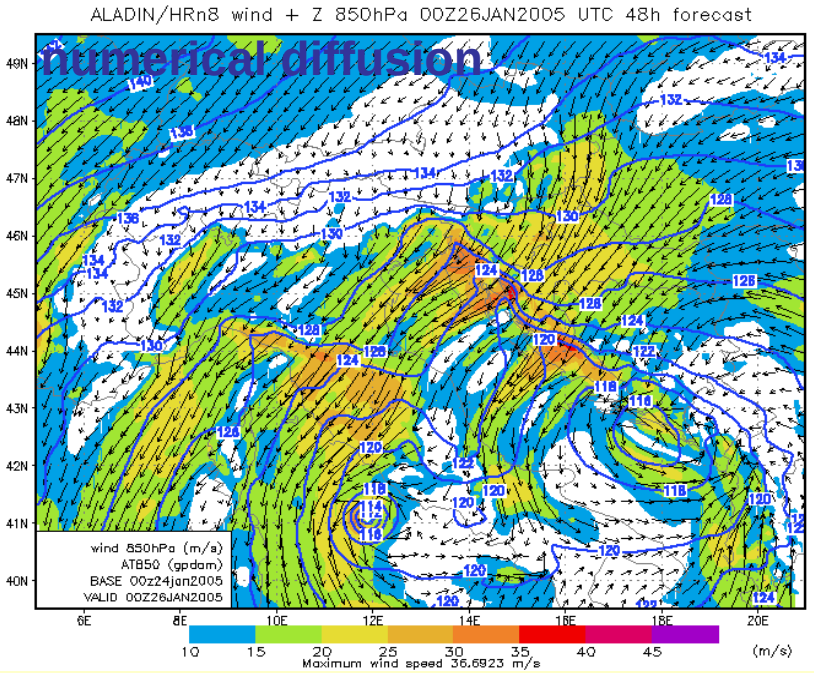
AT500 and wind obtained with numerical diffusion (top left), SLHD (top) and their difference (left), 42 hour forecast starting from 00 UTC 12th January 2002.

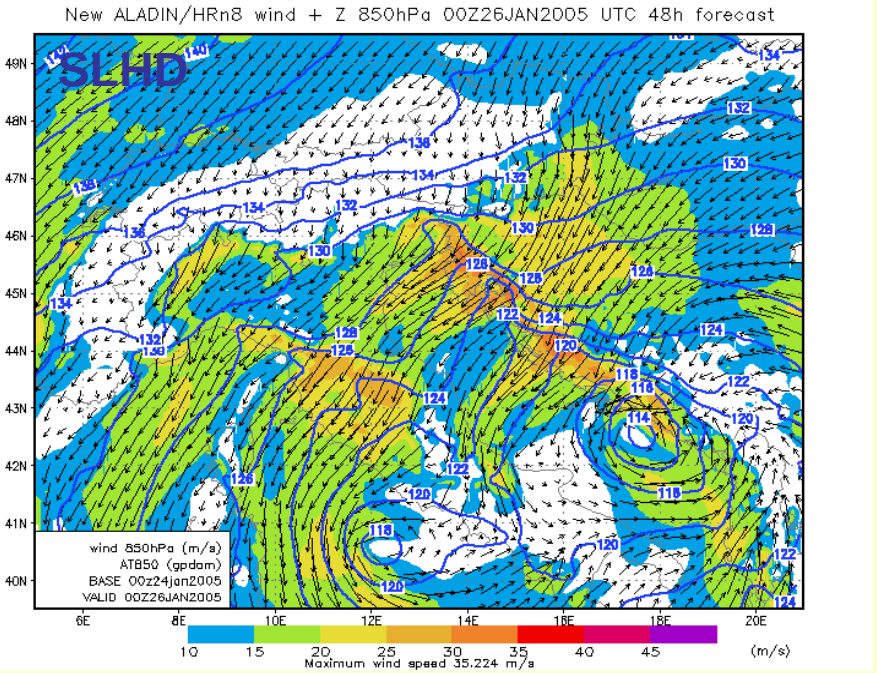


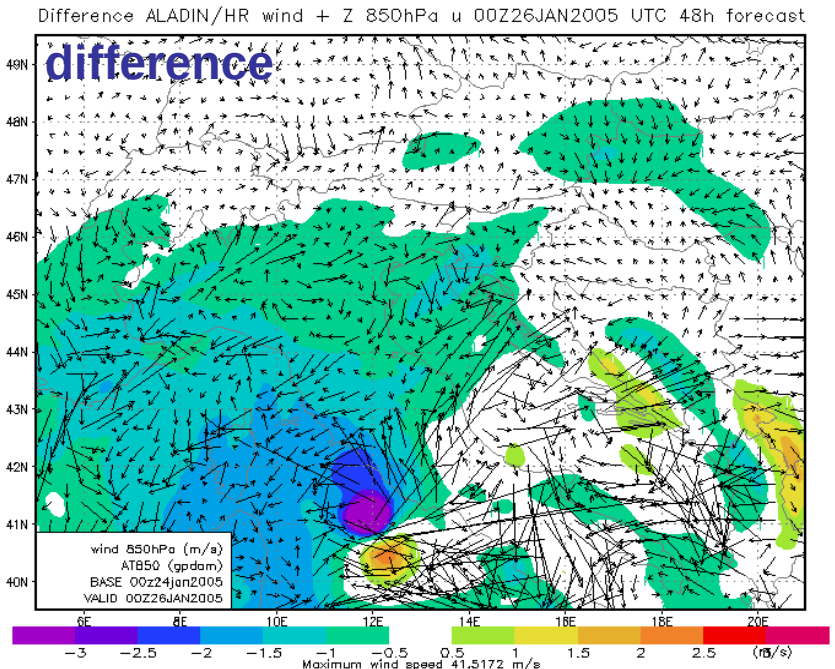




10m wind and mean sea level pressure obtained with numerical diffusion (top left), SLHD (top) and their difference (left), 48 hour forecast starting from 00 UTC 24th January 2005.

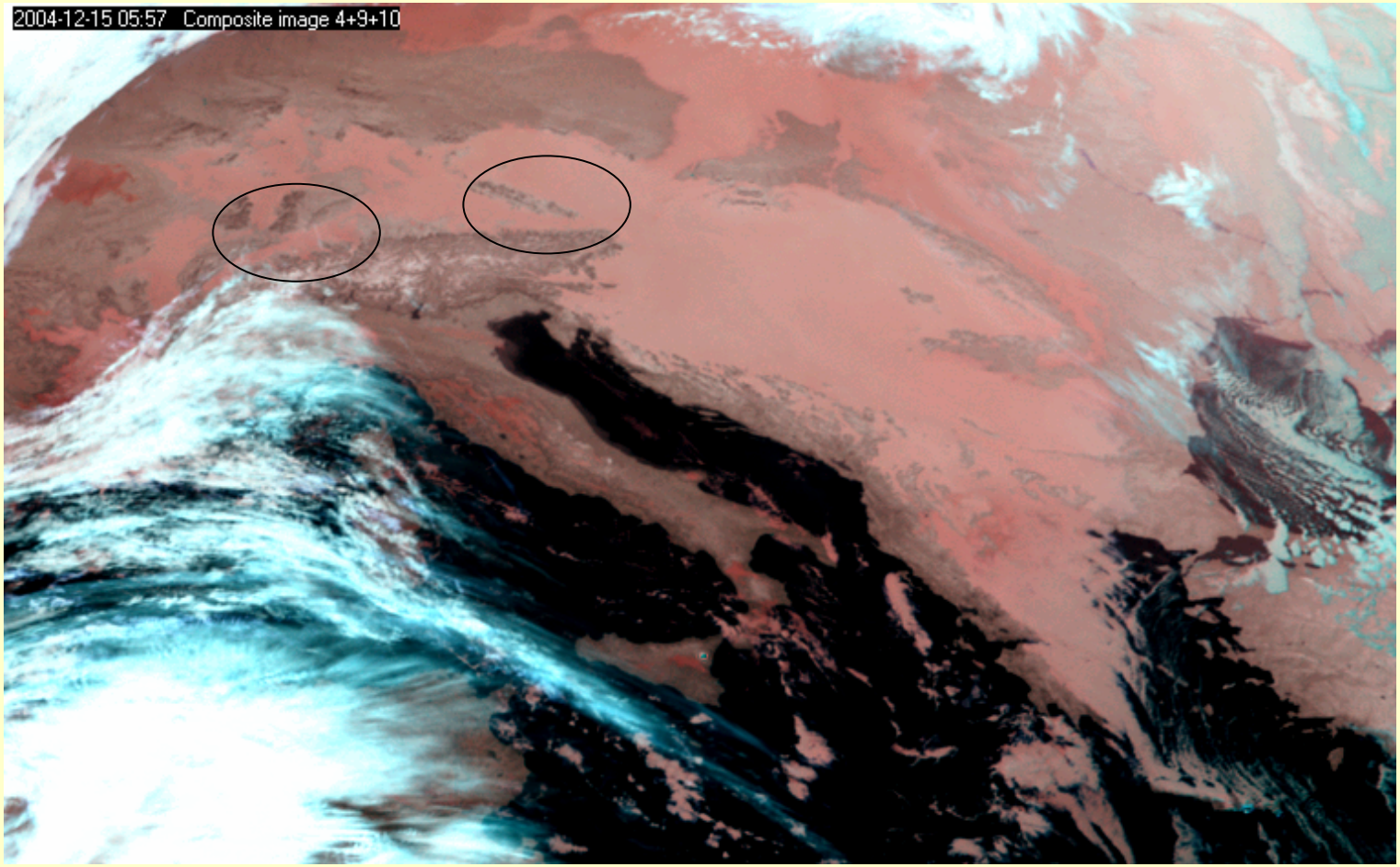






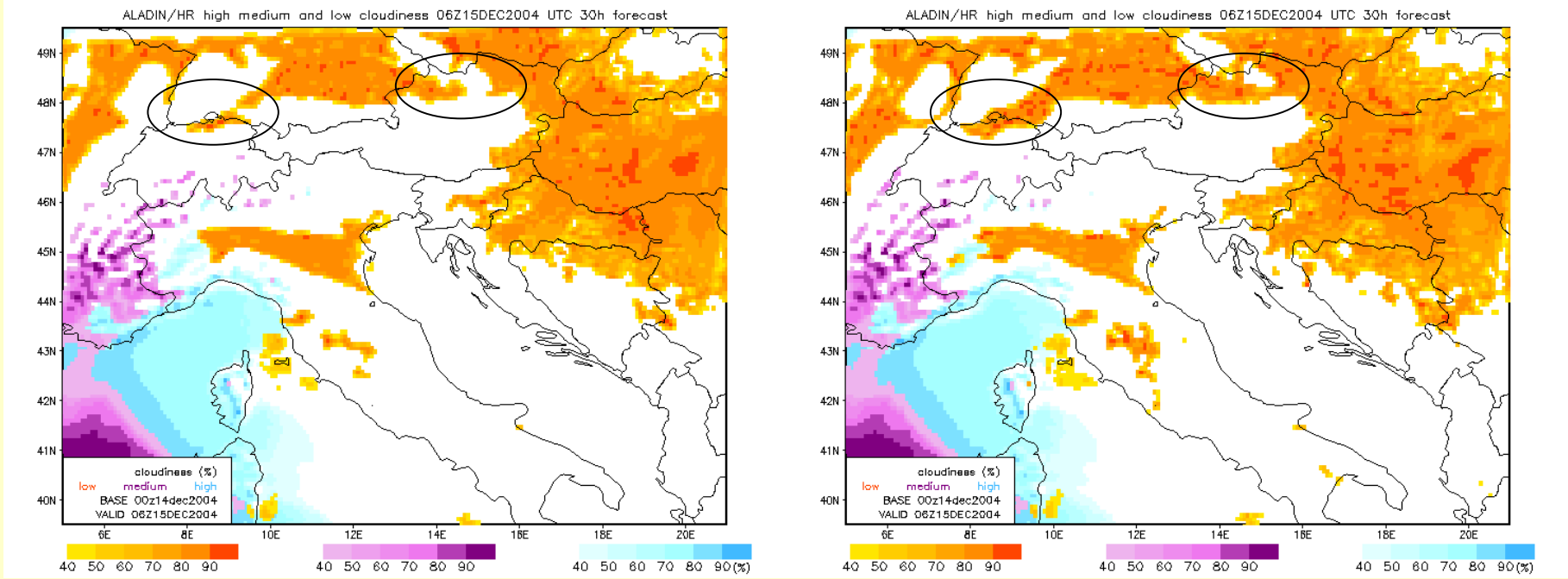
AT850 and wind obtained with numerical diffusion (top left), SLHD (top) and their difference (left), 48 hour forecast starting from 00 UTC 24th January 2005.

Fog case



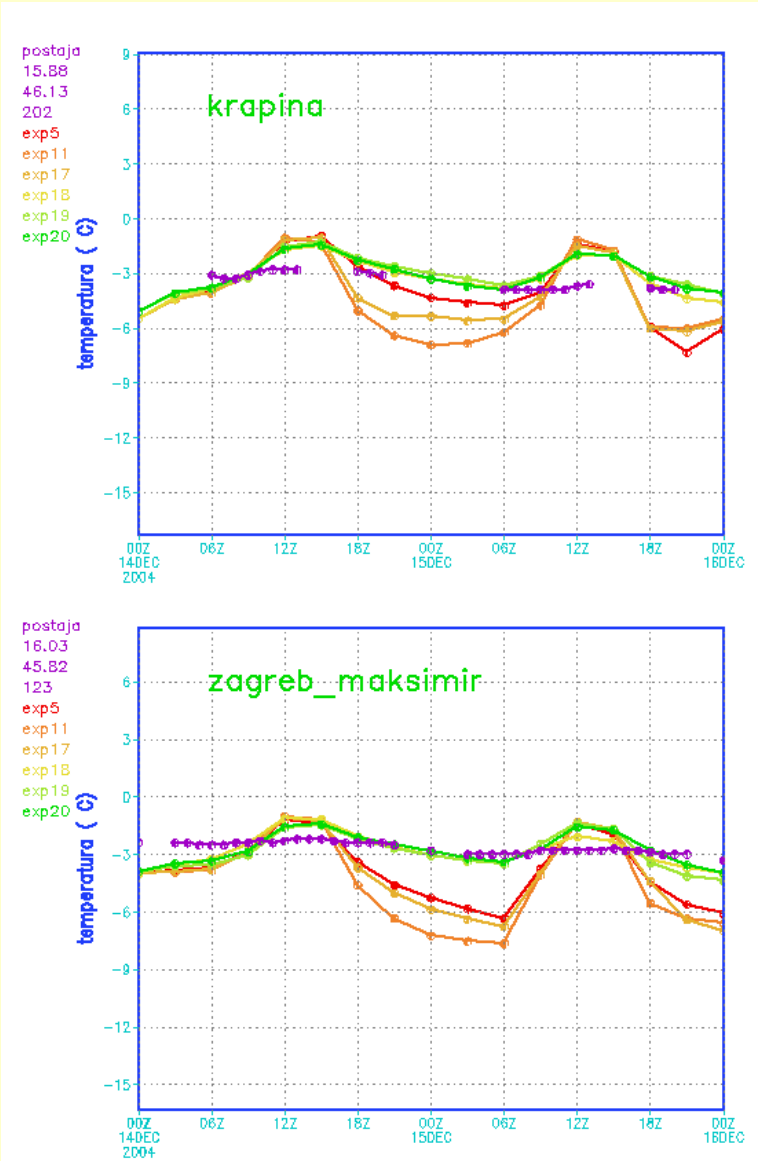
- Meteosat-8 RBG composite of channels 3.9, 10.8 and 12.0 μm for December 15th 2004, 06 UTC.

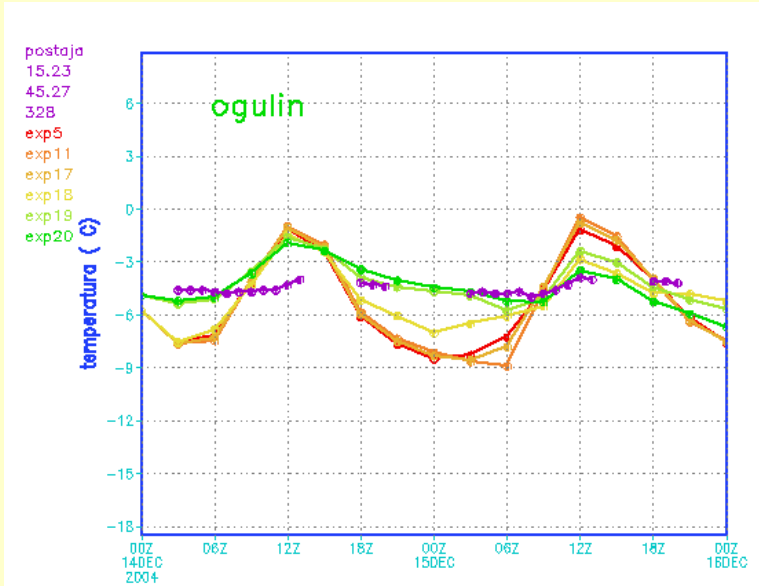
Fog case



- 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

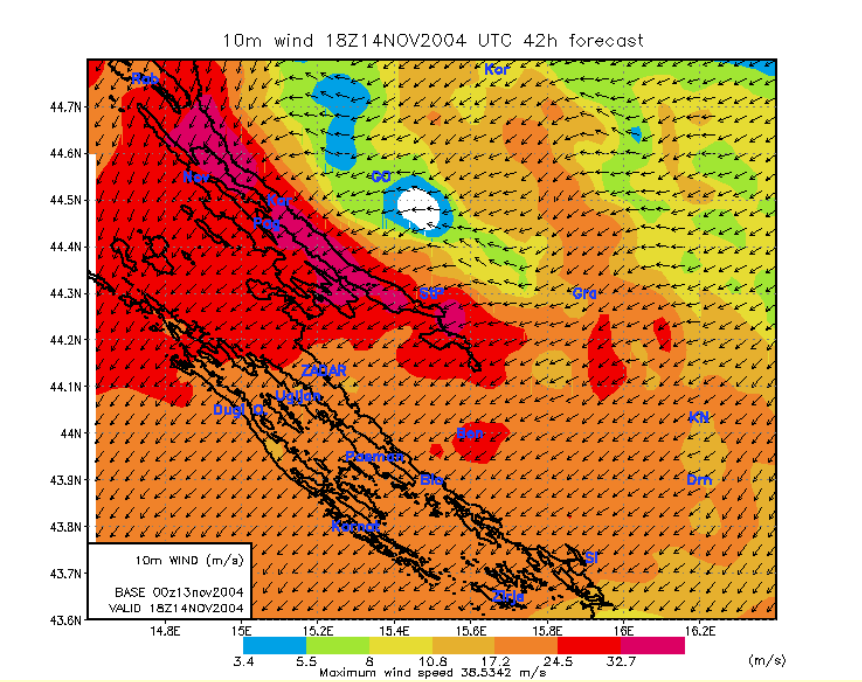
reference
NER
LRAUTOEV
SLHD
mean orog
SLHD+m.o.

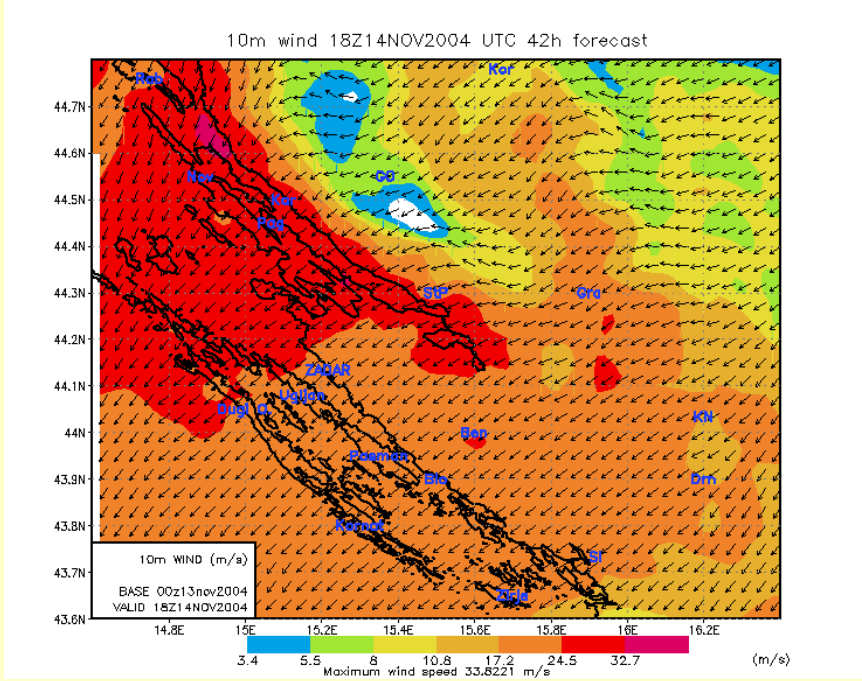
High resolution cases

- two cases of bura:

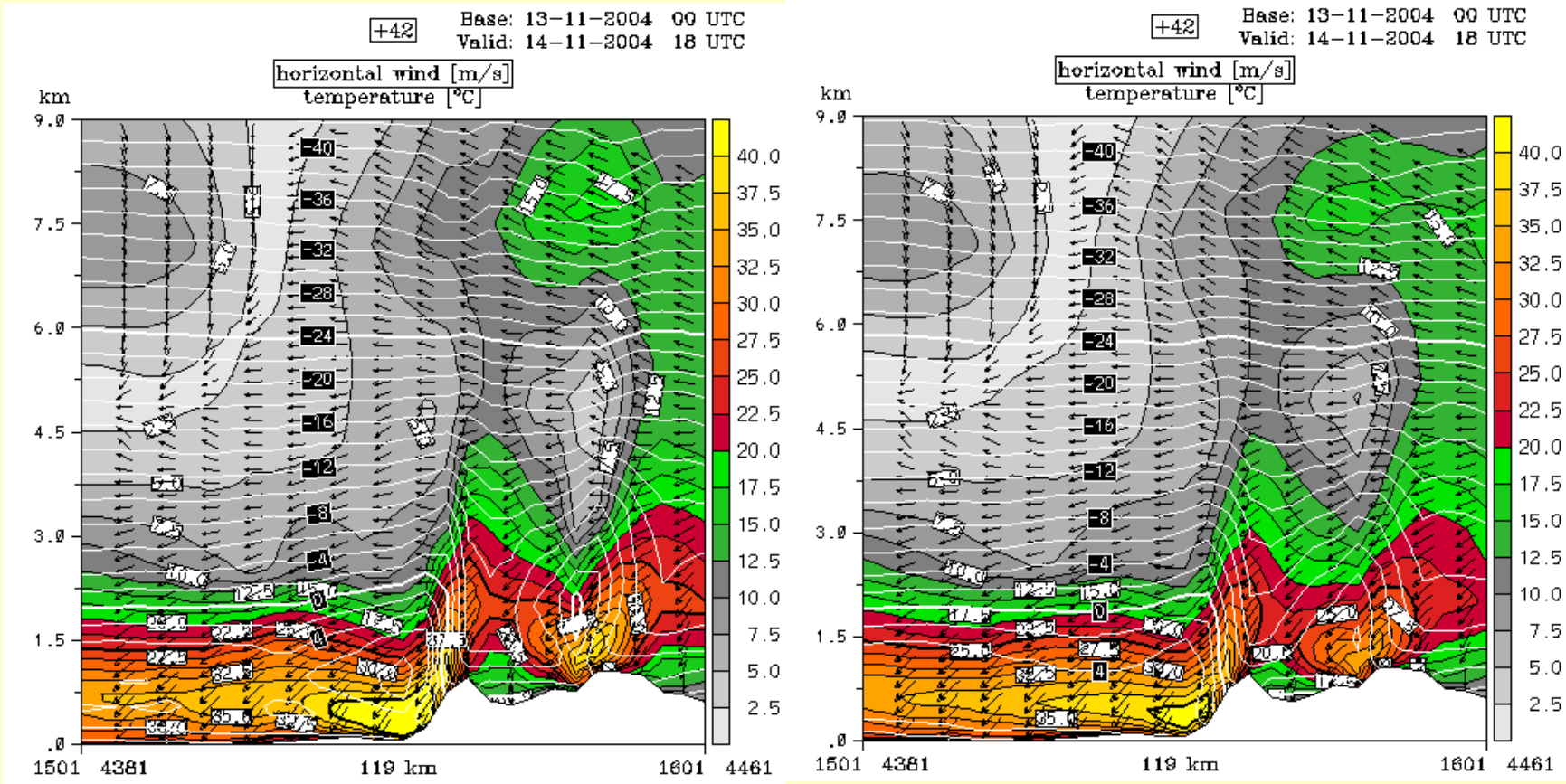
- 14th November 2004, severe bura
- 4th November 2003: very weak and localized in the area close to the town of Senj

- 14th November 2004



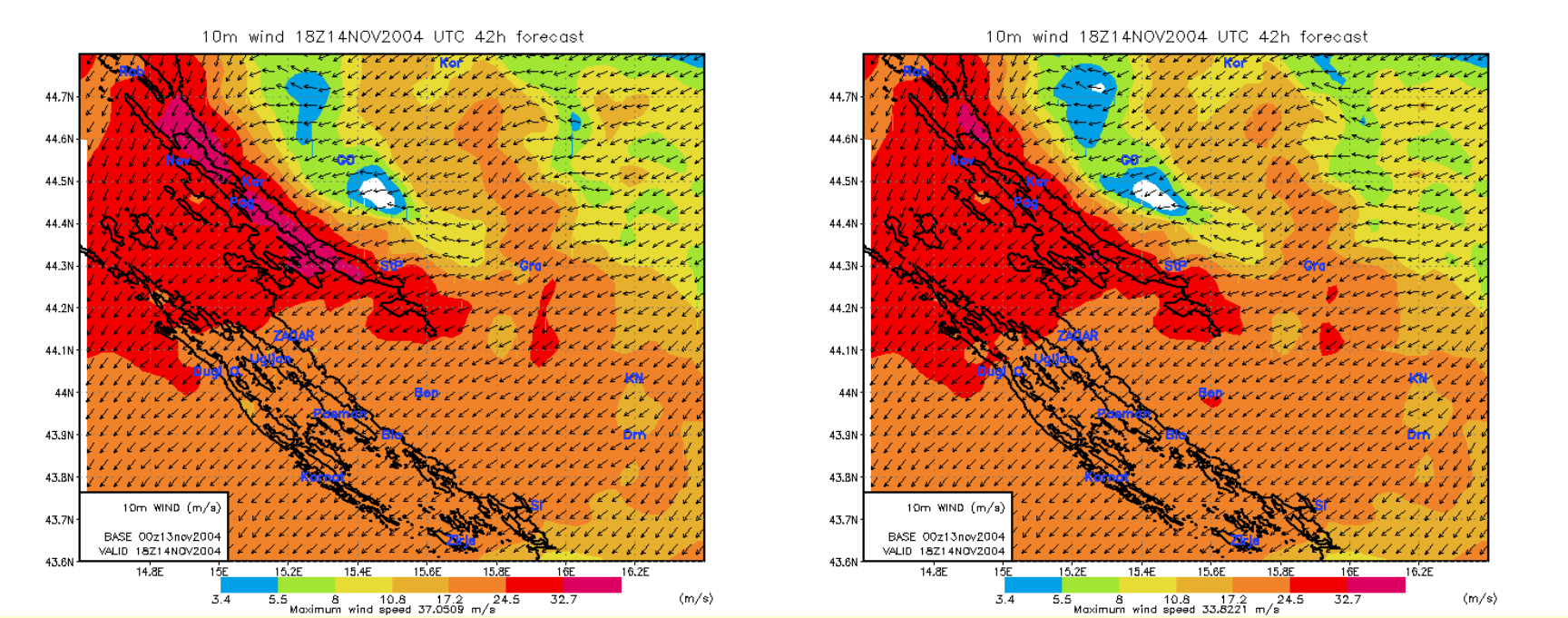


- 10m wind, hydrostatic (left) and nonhydrostatic (right)
- 42 hour forecast starting 00 UTC 13th November 2004
- maslenica domain

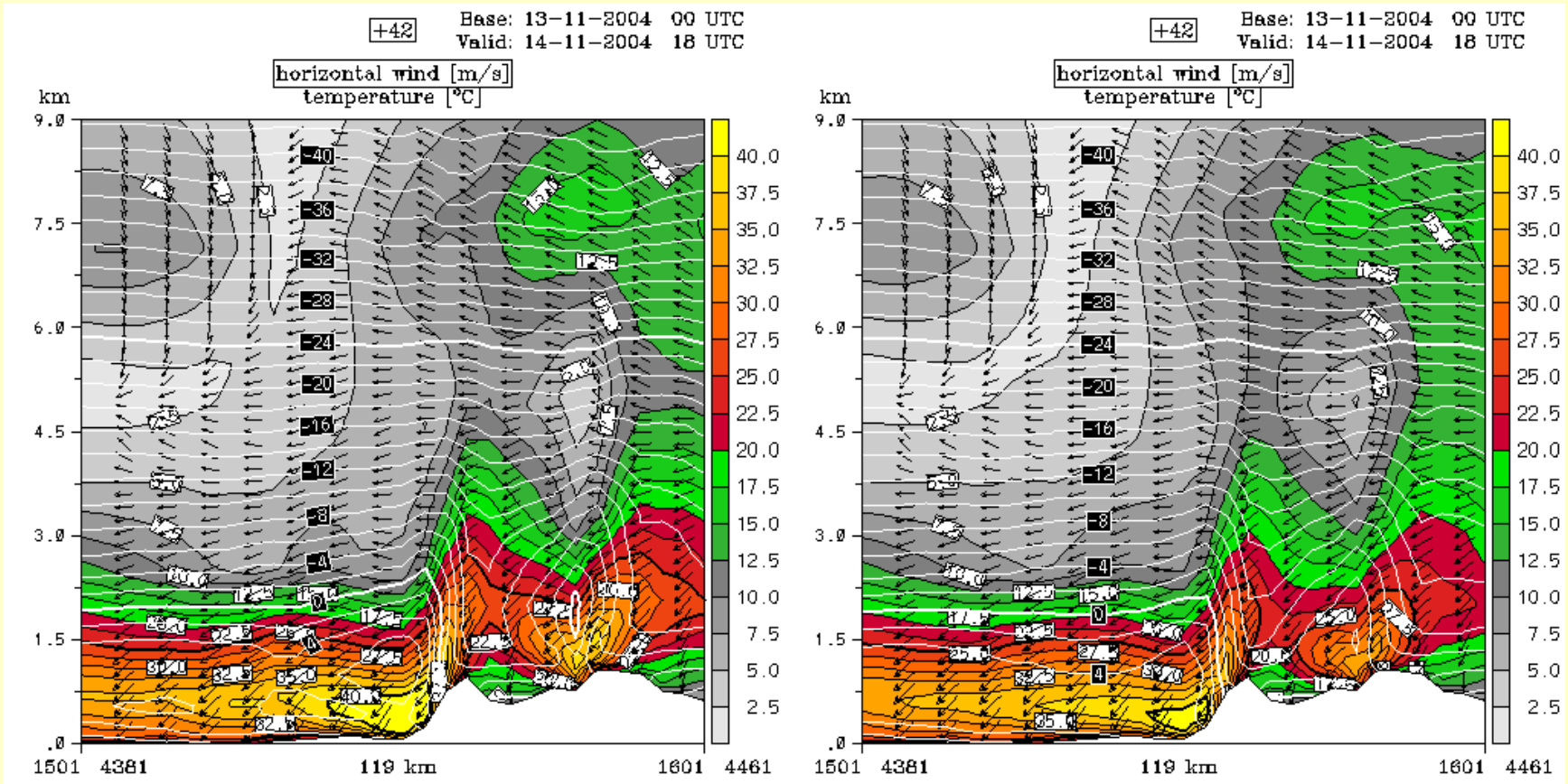


- vertical cross-section of horizontal wind
- 42 hour forecast starting 00 UTC 13th November 2004
- hydrostatic (left) and nonhydrostatic (right)

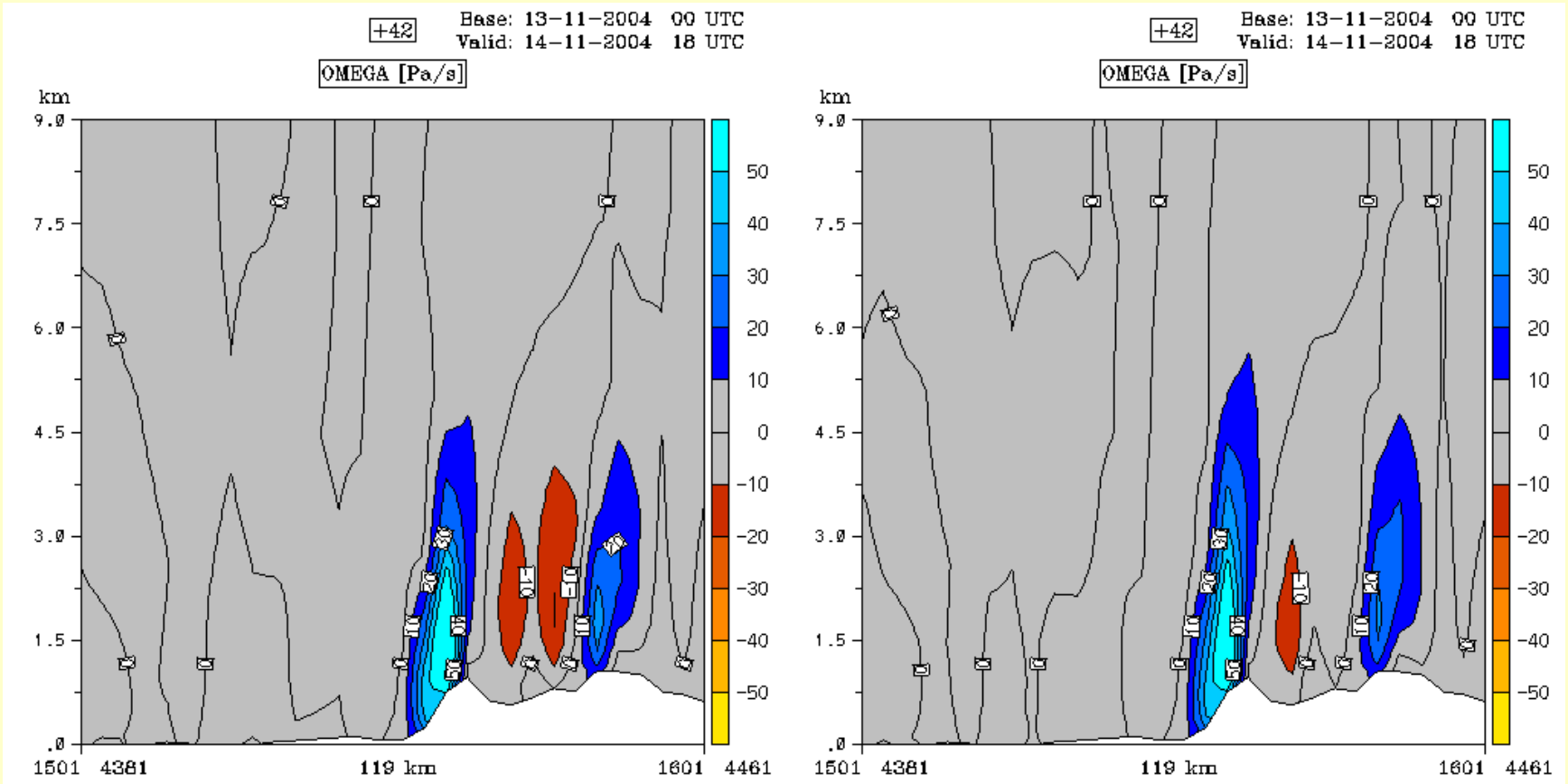
- 14th November 2004



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



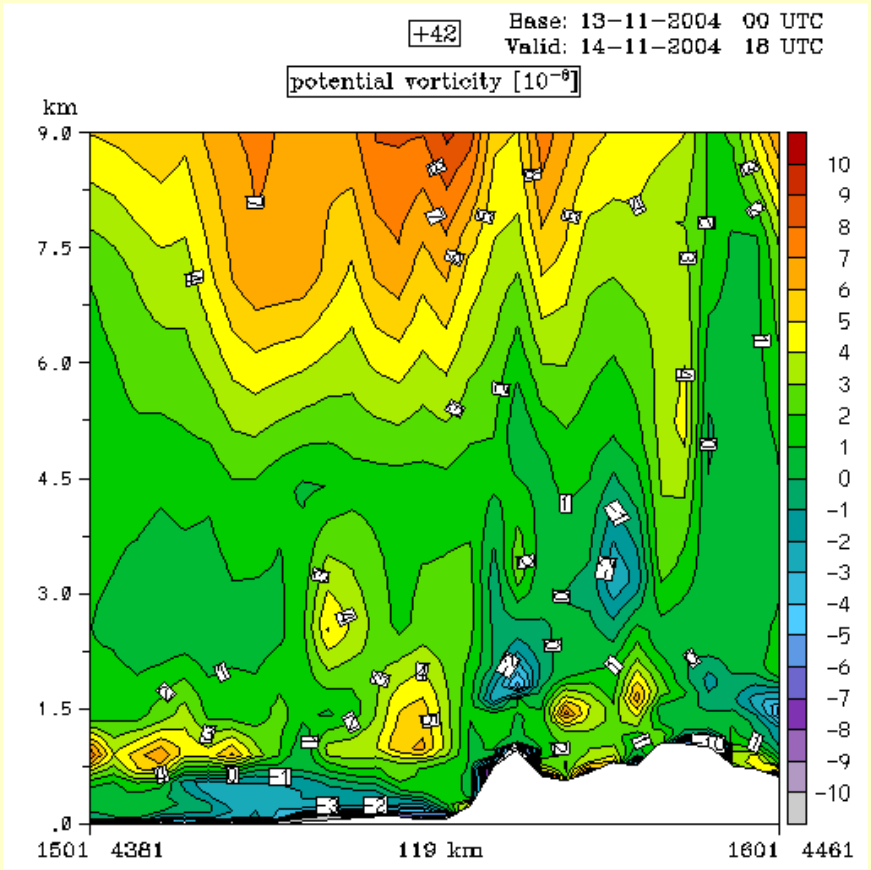
- vertical cross-section of horizontal wind
- 42 hour forecast starting 00 UTC 13th November 2004
- numerical diffusion (left) and SLHD (right)

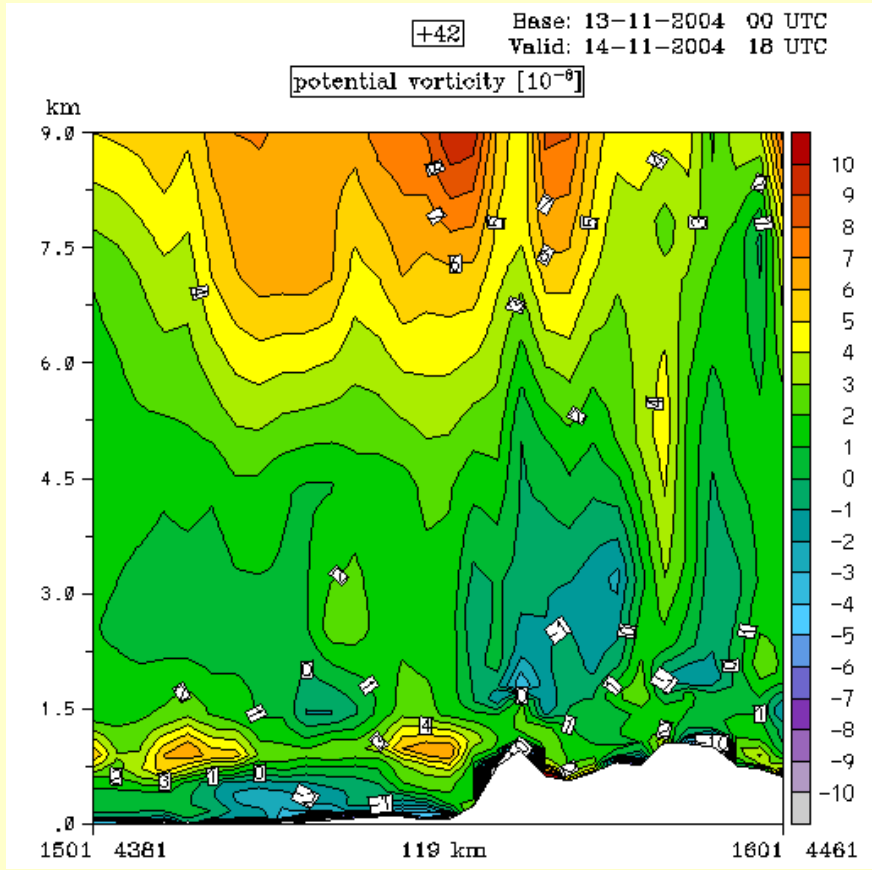


–vertical cross-section of vertical wind speed (omega)

–42 hour forecast starting 00 UTC 13th November 2004

–numerical diffusion (left) and SLHD (right)



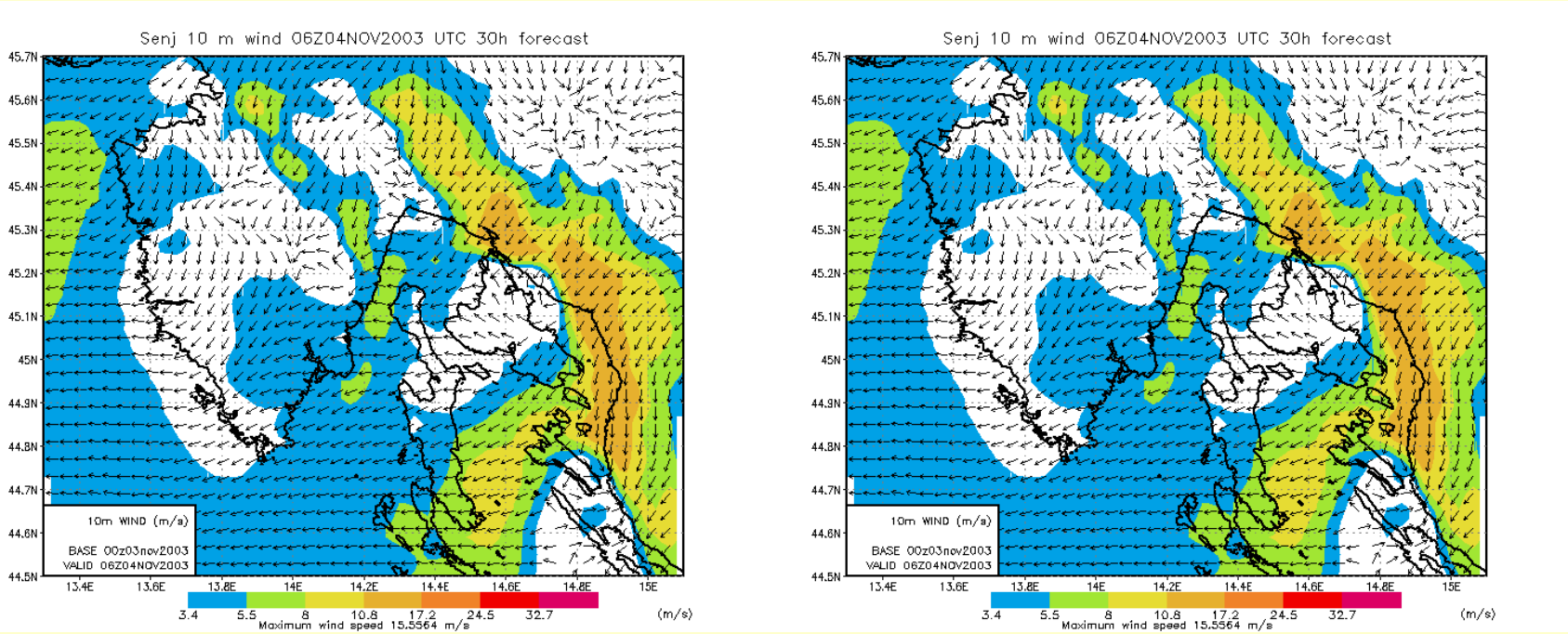


–vertical cross-section of vertical potential vorticity

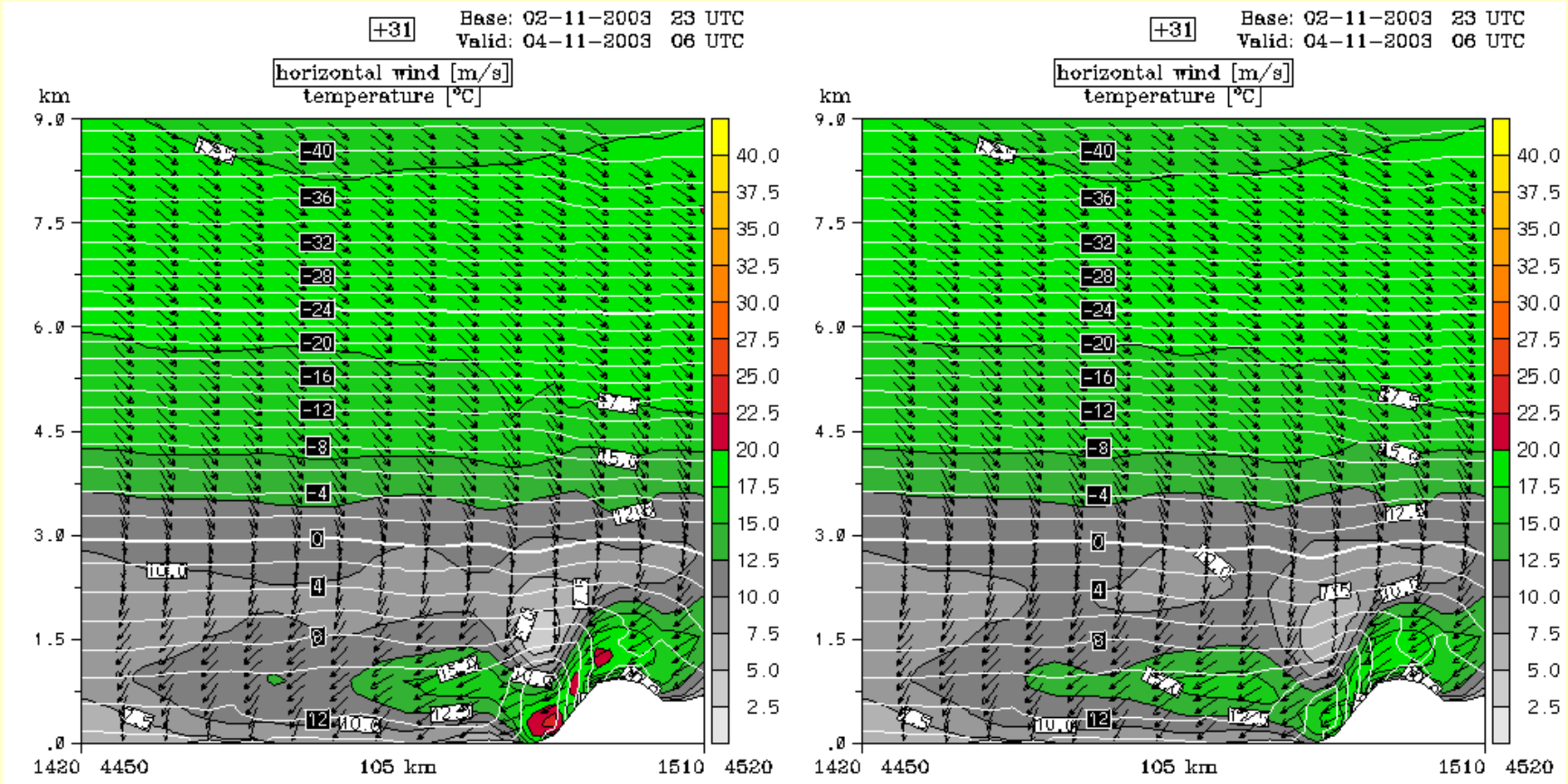
–42 hour forecast starting 00 UTC 13th November 2004

–numerical diffusion (left) and SLHD (right)

4th November 2003



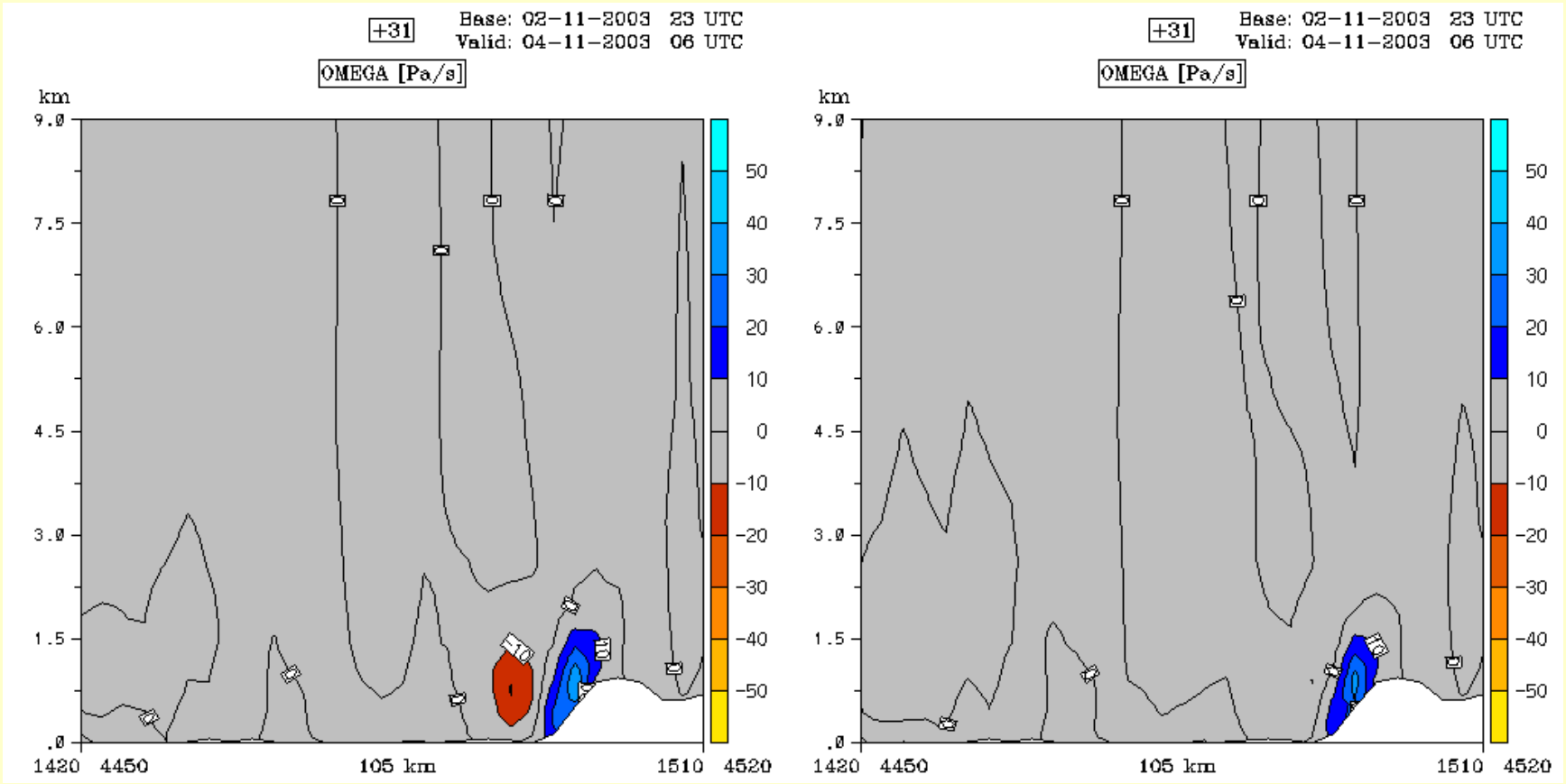
- 10m wind, numerical diffusion (left) and SLHD (right)
- 30 hour forecast starting 00 UTC 3rd November 2003
- Senj domain



–vertical cross-section of horizontal wind

–30 hour forecast starting 00 UTC 3rd November 2003

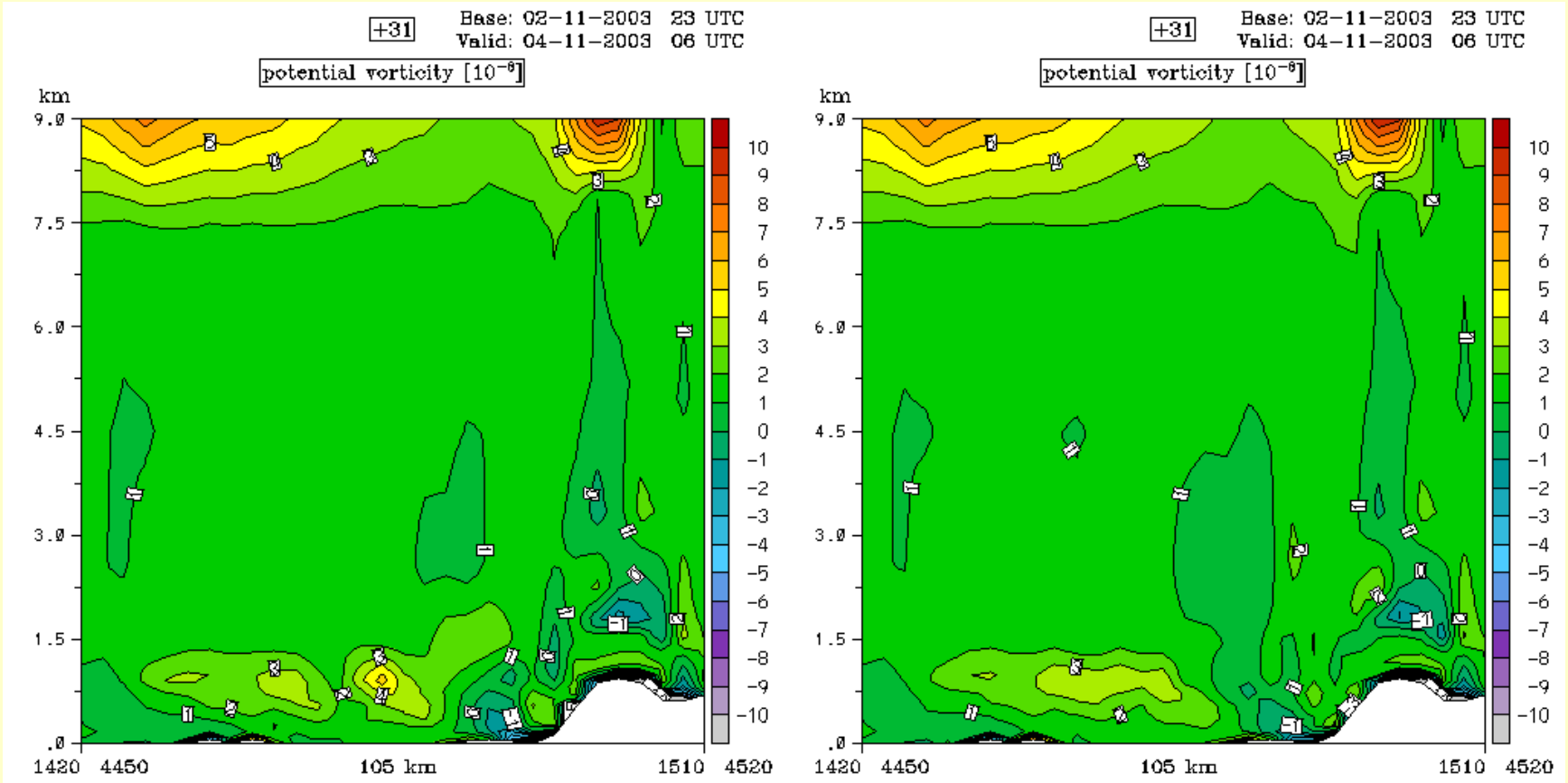
–numerical diffusion (left) and SLHD (right)



–vertical cross-section of vertical wind speed (omega)

–30 hour forecast starting 00 UTC 3rd November 2003

–numerical diffusion (left) and SLHD (right)



–vertical cross-section of vertical potential vorticity

–30 hour forecast starting 00 UTC 3rd 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 and correction of cyclone position while not altering a good intensity prediction,
  - improvement of fog forecast in the valleys in an anticyclone
- In high resolution (2 km) it might need to be retuned