IMPACT OF THE NON-HYDROSTATISM AND THE NEW SEMI-LAGRANGIAN HORIZONTAL DIFFUSION SCHEME ON HIGH-RESOLUTION FORECAST OF BURA USING ALADIN MODEL

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Abstract: A case of severe bura (Adriatic bora) of 14th November 2004 represents a hard real case test for the non-hydrostatic dynamics of Aladin model. A stable and efficient non-linear horizontal diffusion, based on the control of the degree of interpolation needed for the Semi-Lagrangian advection scheme, has been implemented in ALADIN. Both have been used as well as other possible options to improve the forecast of severe bura on 1st and 3rd February 2007.

Keywords: *Aladin non-hydrostatic dynamics, semi-Lagrangian horizontal diffusion, bura*

1. INTRODUCTION

The importance of non-hydrostatic effects in the case of stratified flow over isolated mountain has been studied in several (mostly academic) studies using various analytical and numerical models. These effects will be studied using Aladin model in 2 km horizontal resolution with hydrostatic and non-hydrostatic dynamics for the real flow over real mountains on several real cases of bura (Adriatic bora) in the area of Dynaric Alps (Velebit mountain).

The horizontal diffusion schemes in operational numerical models remove the energy accumulated due to finite truncation of a model spectrum acting as a numerical filter. The usual 4th order numerical horizontal diffusion has been replaced with the Semi-Lagrangian horizontal diffusion (SLHD) based on physical properties of the flow. SLHD is a stable and efficient non-linear horizontal diffusion, based on the control of the degree of interpolation needed for the semi-Lagrangian advection scheme that depends on the local flow. SLHD provides a flow-dependant horizontal diffusion a sort of first step towards a 3D turbulence.

2. METHODS

The operational model version as described in Ivatek-Šahdan and Tudor (2004) changed since a 4th order numerical diffusion scheme has been replaced with SLHD. This scheme has been developed (Vańa 2003, Vańa et al. 2006) controls the horizontal diffusion intensity using local physical properties of the flow and acts horizontally. In the Semi-Lagrangian advection scheme, the origin point is found by interpolation. The interpolator characteristics (the degree of interpolation) depend on the local flow yielding a horizontal diffusion based on physical properties of the flow. Simon and Vaña (2004) have shown that physical horizontal diffusion should not be neglected when the horizontal component of the turbulent mixing is stronger than the vertical one. This could be in situations with strong horizontal wind shear, but also in statically stable situations.

Fully elastic non-hydrostatic dynamical kernel has been developed for Aladin model (Bubnova et al. 1995, Bénard et al. 2004, 2005). Its stability and accuracy allows relatively long time-steps, as long as for the hydrostatic run. A prognostic scheme for turbulent kinetic energy (Geleyn et al. 2006) as well as for cloud water and ice, rain and snow (Catry et al. 2007) have been introduced.

3. RESULTS AND DISCUSSION

A case of severe bura on 14th November 2004 was chosen for the first set of experiments. The experiments were performed using Aladin model on 80x80 points domain with 2km resolution starting from the operational 8km resolution 42 hour forecast that started from 00UTC analysis of 13th November 2004. The model was run for 30 minutes with 1 minute time-step using. Turbulent diffusion is the only parameterization used. Other parameterized processes are switched off.

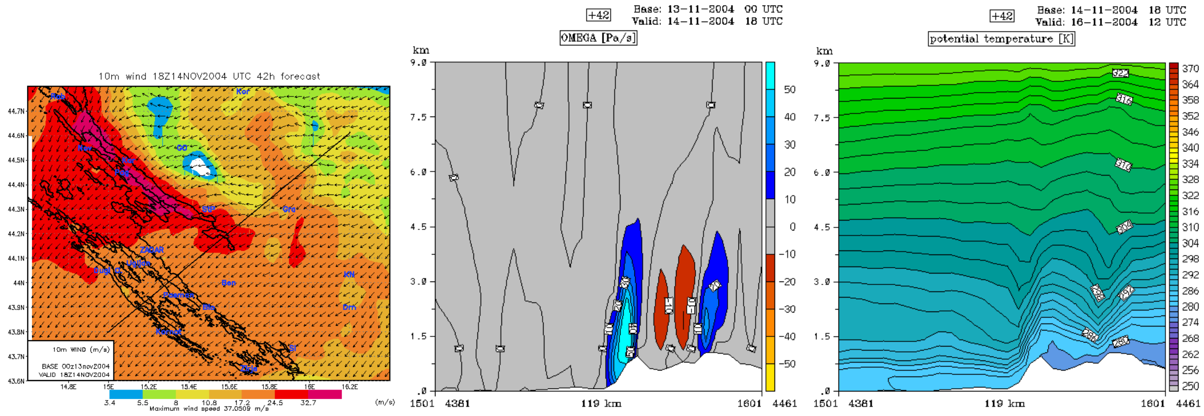

Figure 1: 10m wind (left), vertical corss-sections of omega vertical velocity (center) and potential temperature (right) through the black line on the left panel.

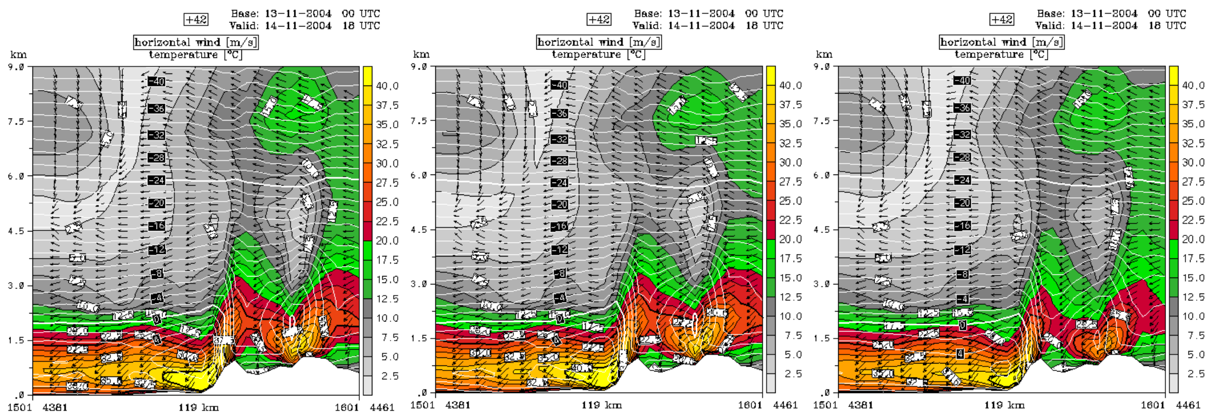

Figure 2: Vertical cross-section of horizontal wid speed (shaded), direction (arrows) and temperature (white lines) across the Velebit mountain, hydrostatic run with numerical diffusion (left), non- hydrostatic run with numerical diffusion (center) and hydrostatic run with SLHD (right).

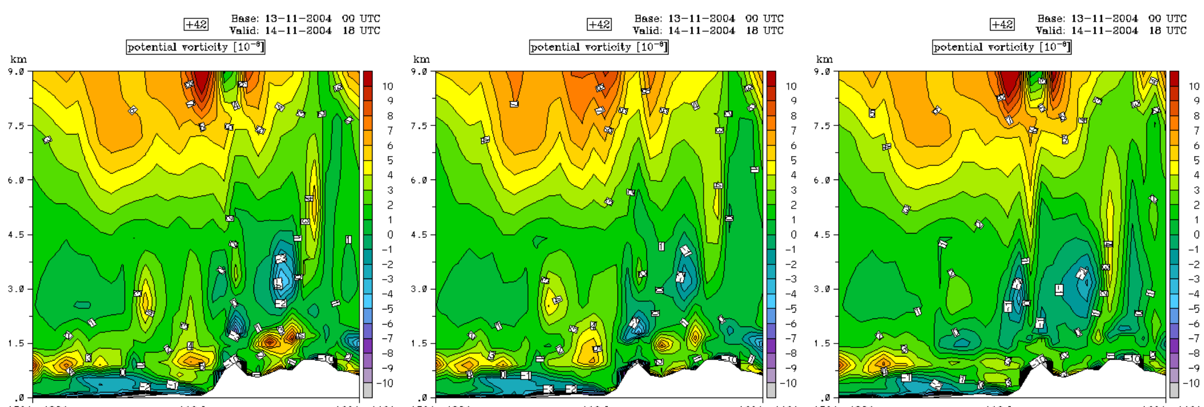

Figure 3: Vertical cross-section of potential vorticity across the Velebit mountain, hydrostatic run with numerical diffusion (left), non- hydrostatic run with numerical diffusion (center) and hydrostatic run with SLHD (right).

The 2km resolution dynamical adaptation of the wind field is used to provide a high-resolution operational forecast of the 10m wind. The impact of non-hydrostatic dynamics and SLHD on the predicted 10m wind is not significant, but it becomes so higher in the atmosphere. The simulated wind speed 10 m above ground in 2 km horizontal resolution is only slightly lower with non-hydrostatic dynamics than with the hydrostatic one for a case of severe bura on the steepest mountain slopes. Introduction of SLHD has a strong impact on the simulated hydraulic jump and reduces the 10m wind speed below it, downstream of the mountain obstacle. SLHD reduces the speed of the downslope jet, the static stability in the jet and the hydraulic jump in vertical velocity field. It also reduces the feature in the temperature filed just after the first obstacle, about 1.5 km height. Both non-hydrostatic dynamics and SLHD have a strong impact on the PV (potential vorticity) field in the low troposphere reducing the high PV values in the vicinity of the orographic obstacles.

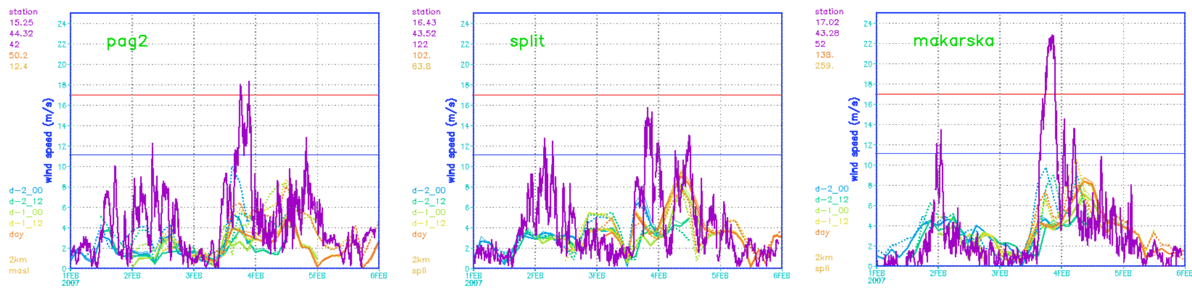

Figure 4: Measured (dark purple) and predicted 10m wind speed using Aladin model with 8km (full lines) and 2km (dashed) horizontal resolution for several points Pag (left), Split (center) and Makarska (right).

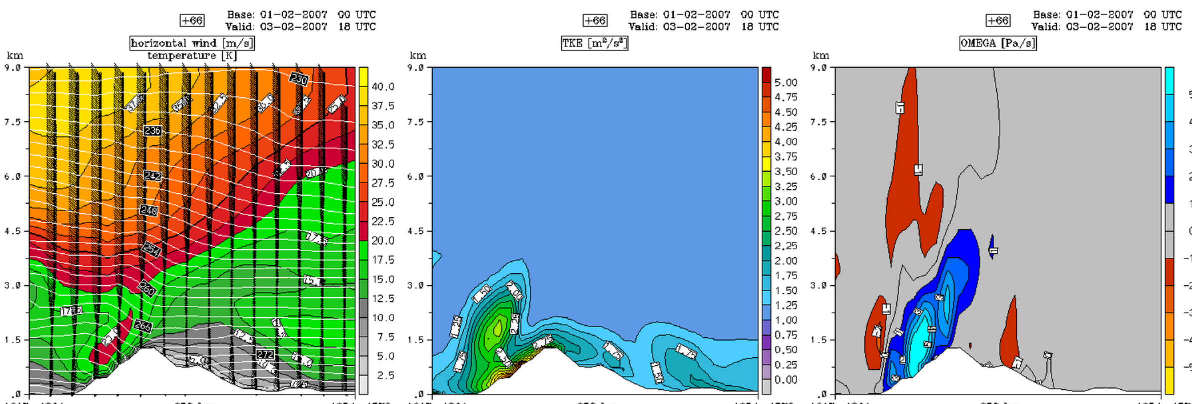

Figure 4: Vertical cross-section of horizontal wind speed (shaded), direction (arrows) and temperature (white lines) (left), TKE (center) and omega vertical velocity (right) across the mountain through Split, 66 hour 8km horizontal resolution forecast with hydrostatic dynamics and SLHD.

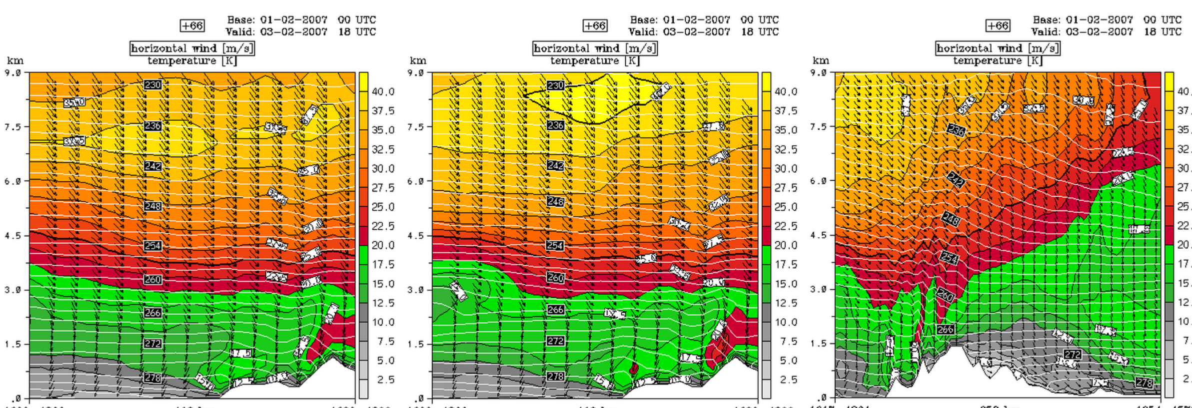

Figure 5: Vertical cross-section of horizontal wind speed (shaded), direction (arrows) and temperature (white lines) 2km hydrostatic resolution dynamical adaptation on 15 levels (left), 37 levels (center) and full 2km resolution hydrostatic forecast on 37 levels (right), all runs with SLHD.

The second case of 1st – 2nd and 3rd February represents two cases of failed forecast of bura. Measured wind speed was almost twice the forecasted one. A high level northwesterly jet moves across Croatia southwestward. The high level wind is parallel to the mountain range, but further upstream it is almost perpendicular to the Alps.

Vertical cross sections of the wind field (Figure 4, left panel and Figure 5) show increased wind speed down the slope of the mountain upstream of Split, but not for the Split situated just on the coast. The wind vectors above 3km are parallel to the mountain. This supports trapped lee waves. Large TKE values 1.5 km above Split are a consequence of breaking waves. Similar features can be observed above other windstorm locations. The operational 2km resolution dynamical adaptation uses only 15 levels, mostly below 3km. But above that height vertical resolution is too low to allow correct modelling of this high level jet. When vertical resolution is increased, the wind speed in the low level downslope jet increases slightly.

Full 2km resolution 66 hour forecast starting from 00 UTC analysis on 1st February 2007 did not improve the forecast much for both cases, either in hydrostatic or non-hydrostatic run. High measured 10m wind speed is probably a consequence of the high level jet tongue that run down the slope of the mountain for several hours. It remains a challenge to find why it is not forecasted.

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