ALADIN/HR: TESTING THE NEW SEMI-LAGRANGIAN HORIZONTAL DIFFUSION SCHEME

Martina Tudor, Vlasta Tutiš, Dunja Drvar, Ivana Stiperski and Filip Vaña

Croatian Meteorological and Hydrological Service, Grič 3, 10000 Zagreb
E-mail: tudor@cirus.dhz.hr

Abstract: Main role of the horizontal diffusion schemes in numerical models nowadays is to remove the information without forecast value and the energy accumulated due to finite truncation of a model spectrum acting as a numerical filter. However, during intensive cyclogenesis, especially over steep surfaces, the physical horizontal diffusion should not be neglected. 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. The results of several numerical experiments show better simulation of a mesoscale Adriatic cyclones, upper troposphere cyclones and beneficial impact on forecast of low cloudiness in anticyclones.

Keywords *Semi-Lagrangian, horizontal diffusion, Adriatic cyclone*

1. INTRODUCTION

Main form of horizontal diffusion commonly used in NWP models is the numerical diffusion acting as a numerical filter and selectively damping short waves. It is usually applied on model levels that often follow orography, thus it is not purely horizontal. Physical horizontal diffusion is negligible for low horizontal resolution and requires computationally expensive nonlinear operator realistically describing physical processes.

The significance of the physical horizontal diffusion increases with horizontal resolution. Simultaneously, model levels become more tilted close to mountain areas, making the traditional numerical diffusion acting more and more along the vertical. So the horizontal mixing often occurs between “the valley” and “the mountain top”. This feature of numerical diffusion is more pronounced in cyclogenetic areas surrounded by mountains, like Adriatic Sea surrounded by the Dinaric Alps, Alps and Apennines. 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.

2. METHODS

The operational ALADIN model is conducted with a 4^{th} order numerical diffusion scheme. The operational model version is described in Ivatek-Šahdan and Tudor (2004).

A new scheme has been developed (Vaña 2003, Vaña et al. 2005) controlling the horizontal diffusion intensity using local physical properties of the flow and acting 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. We will call this new scheme Semi-Lagrangian horizontal diffusion (SLDH).

3. RESULTS AND DISCUSSION

3.1. Adriatic cyclones

The 00 UTC run 24 hour forecast starting 20th July 2001 produced very intensive cyclone in the Adriatic. The position was good, but the intensity was overestimated. SLHD reduces the intensity of the cyclone at sea level as well as at 850 hPa and the forecasted 10m wind speed is reduced (Fig 1).

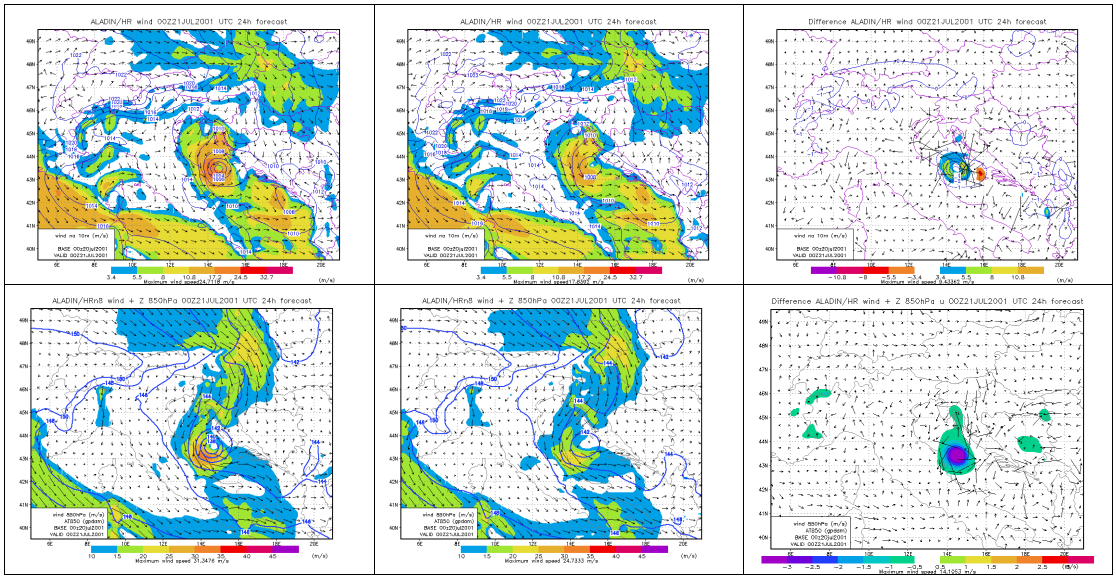

Figure 1. Mean sea level pressure and 10 m wind (top row) and AT850 (bottom row) obtained with classical numerical diffusion (left), Semi-Lagrangian horizontal diffusion (center) and their difference (right), 24 hour forecast starting from 00 UTC 20th July 2001.

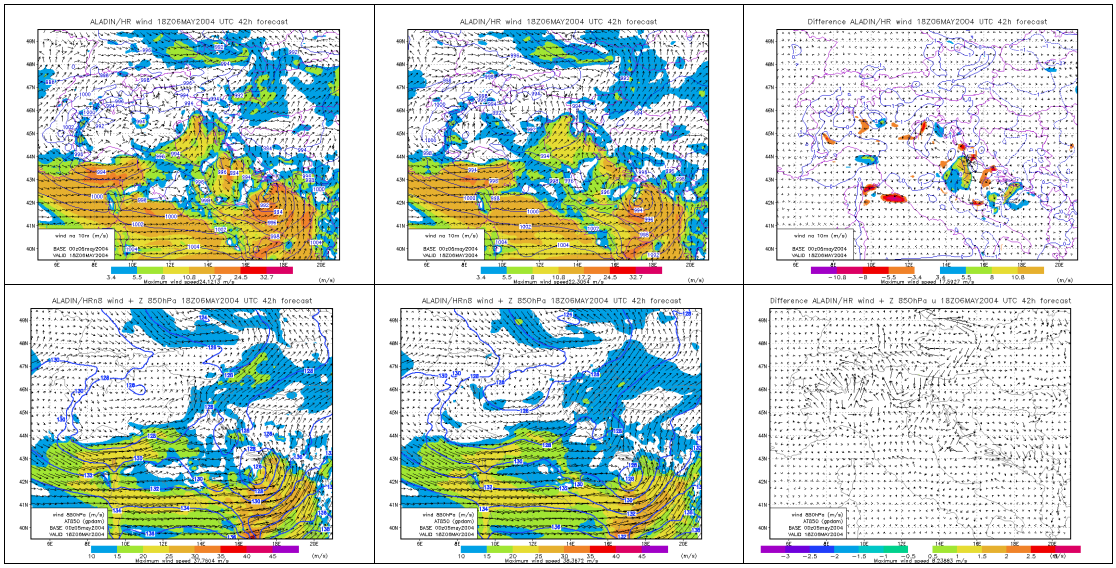

Figure 2. Mean sea level pressure and 10 m wind (top row) and AT850 (bottom row) obtained with classical numerical diffusion (left), Semi-Lagrangian horizontal diffusion (center) and their difference (right), 42 hour forecast starting from 00 UTC 5th May 2004.

It is important, however, to verify that this new scheme will not reduce the intensity of every small cyclone. On 6th May 2004, small but intensive cyclone quickly developed in the Adriatic and crossed it. Its intensity was predicted well, but the trajectory of the cyclone was more to the northwest. In this case, use of SLHD did not reduce the cyclone intensity, but shifted the system a bit in the northwestern direction (Fig 2).

3.2. Upper level cyclone

In the absence of large gradients of horizontal wind close to an orographic obstacle, SLHD acts similarly to the classical numerical diffusion. On 13th January 2002, there was an intense cyclone in the upper troposphere above Central Europe, while lower level geopotential did not show any gradient. Both horizontal diffusion schemes produced similar forecasts with small differences (Fig 3) that correspond to a shift of the cyclone's center to the northeast.

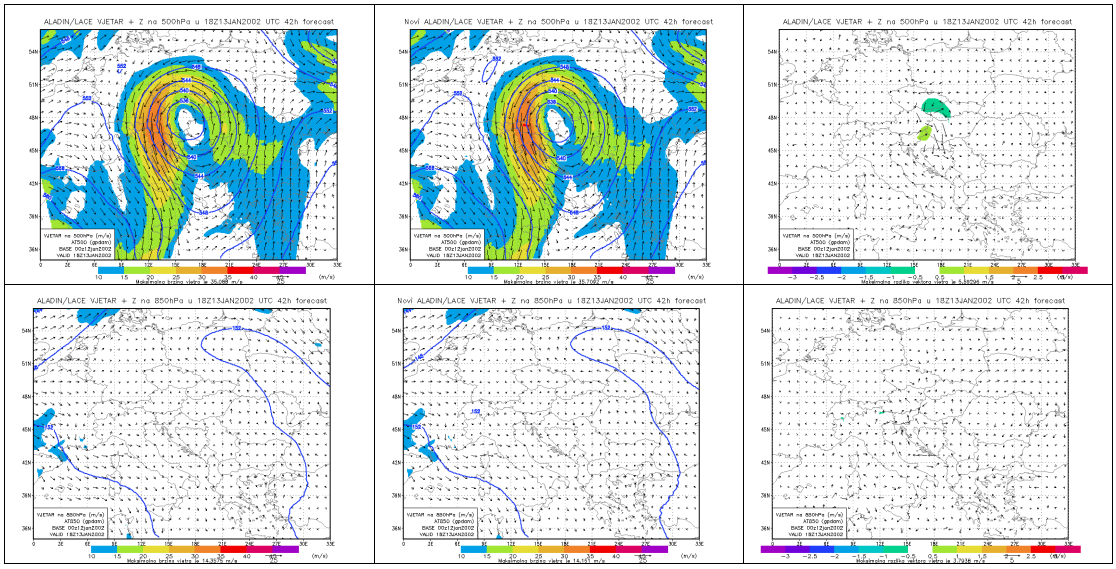

Figure 3. AT500 (top row) and AT850 (bottom row) obtained with classical numerical diffusion (left), Semi-Lagrangian horizontal diffusion (center) and their difference (right), 42 hour forecast starting from 00 UTC 12th January 2002.

3.3. Fog case

In the case of fog in an anticyclone, use of SLHD increases the amount of fog in alpine valleys (Fig 4), especially on the border between Switzerland and Germany and in Danube valley in Austria. Numerical horizontal diffusion acts along model levels mixing the air from the valley with the air above the surrounding peaks. Often it produced a cloud on the mountaintop instead in the valley. SLHD is purely horizontal, so the cloud stays in the valley (Fig 5).

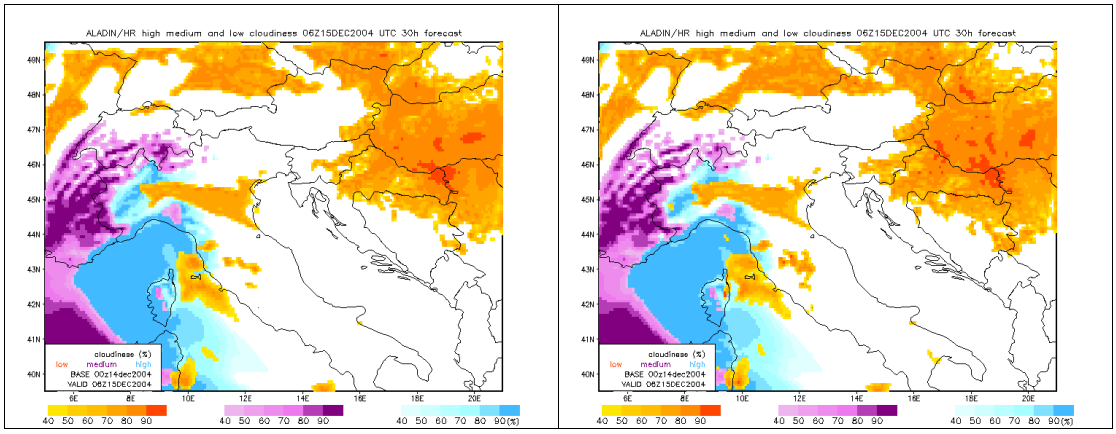

Figure 4. Impact of SLHD on the forecast of low clouds, pure numerical diffusion (left) and SLHD (right).

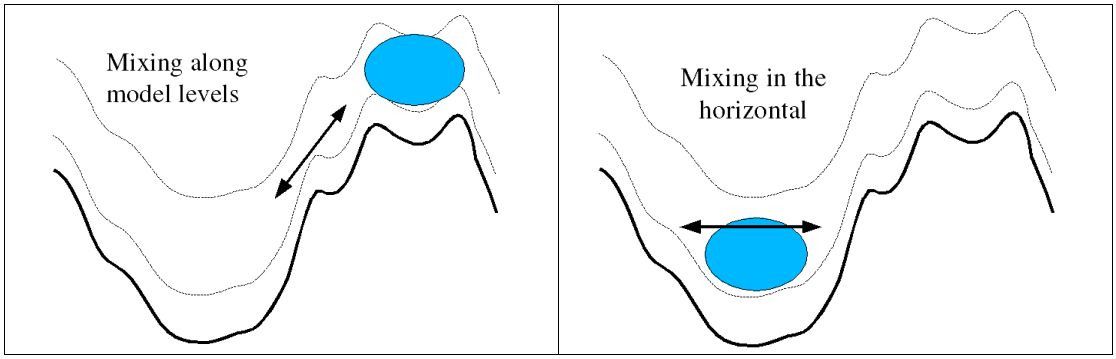

Figure 5. Schemes of impact of horizontal diffusion on cloud formation: numerical (left), SLHD (right).

4. CONCLUSION

SLHD has shown beneficial impact in different cyclonic situations as well as in an anticyclone.

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