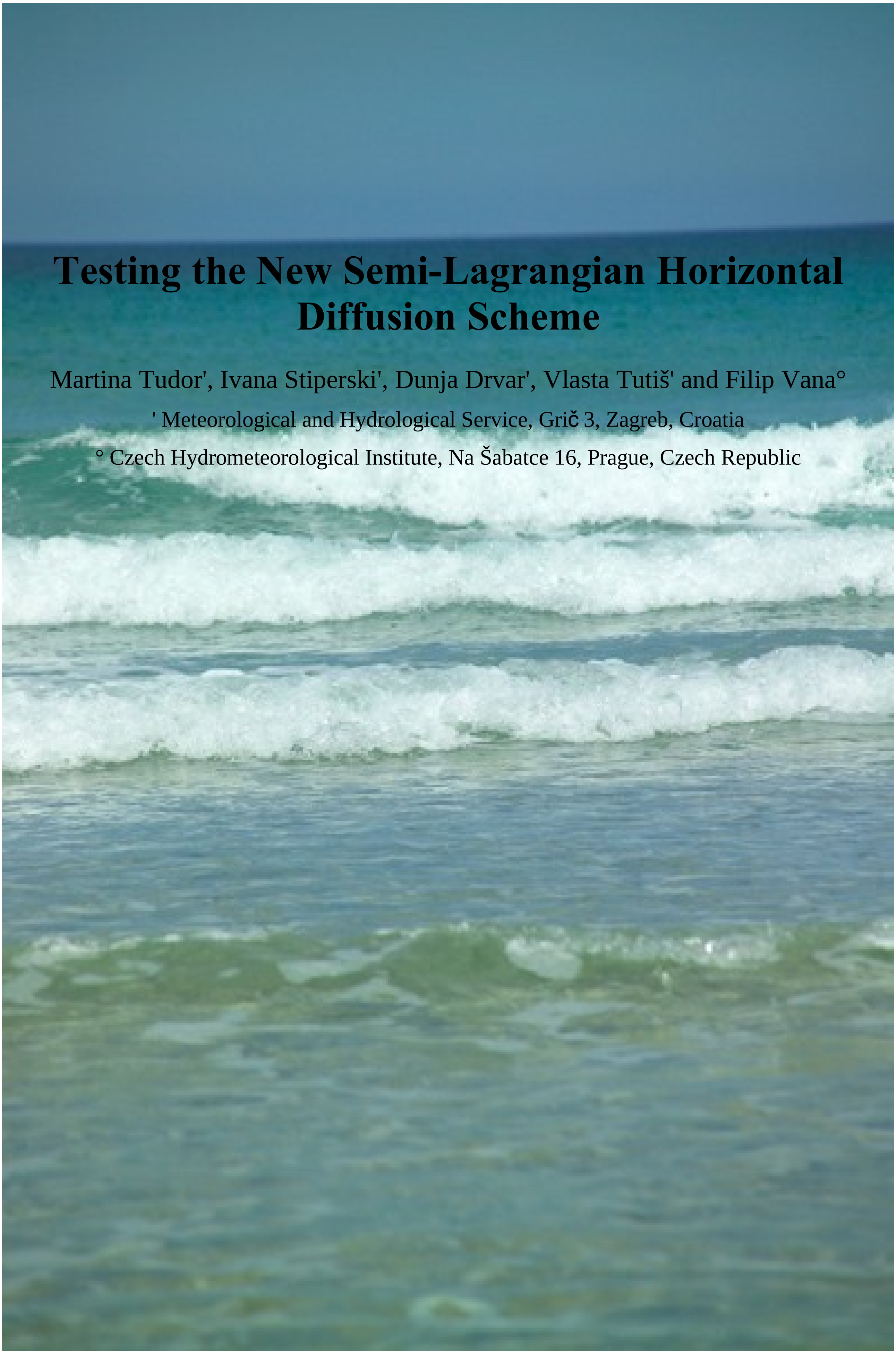

Testing the New Semi-Lagrangian Horizontal Diffusion Scheme

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1. Summary

The 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, hence 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 a better simulation of a mesoscale Adriatic cyclone and upper troposphere cyclones and a beneficial impact on forecast of low cloudiness in anticyclones.

2. Introduction

The main form of horizontal diffusion commonly used in NWP models is the numerical diffusion that acts as a numerical filter and selectively damps short waves. It is usually applied on model levels that often follow orography, so 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 act 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 Dinaric Alps, Alps and Apennines. Simon and Vana (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.

3. Methods

The operational ALADIN model is conducted with a 4th order numerical diffusion scheme. A new scheme has been developed by Filip Vana that controls 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 (SLHD).

4. Results and discussion

4.1 Adriatic cyclones

The 00 UTC run 24 hour forecast starting 20th July 2001 produced a 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).

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).

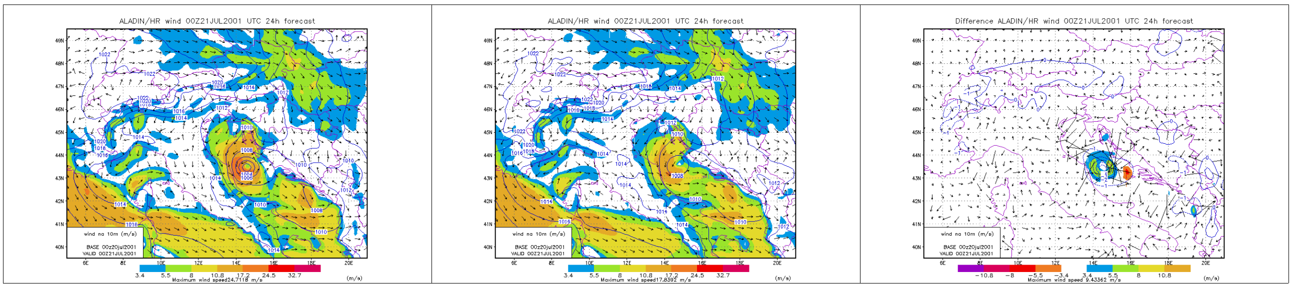

Figure 1. Mean-sea-level pressure and 10 m wind obtained with classical numerical diffusion (left), semi-Lagrangian horizontal diffusion (center) and their difference (right), 24 hour forecast starting from 00 UTC 20th July 2001.

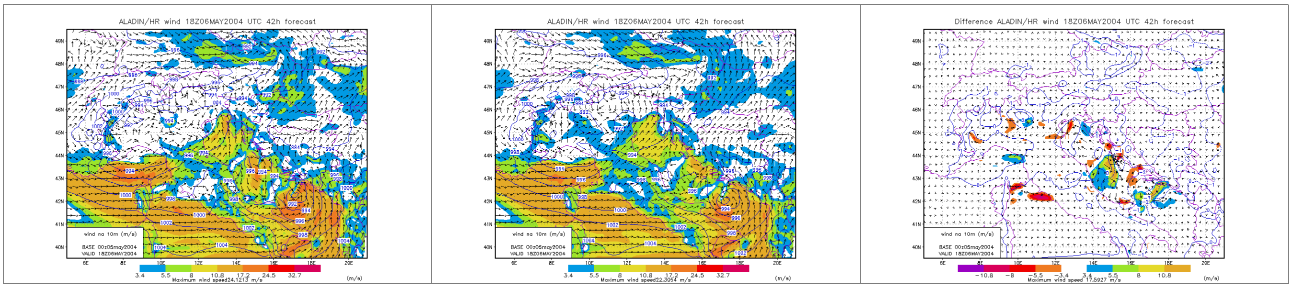

Figure 2. Mean-sea-level pressure and 10 m wind obtained with classical numerical diffusion (left), semi-Lagrangian horizontal diffusion (center) and their difference (right), 42 hour forecast starting from 00 UTC 5th May 2004.

4.2 Twin cyclones

24th January 2005, 00 UTC run produces twin cyclones, one above Tyrhenian Sea and one in the Adriatic. The depth of the Tyrrhenian Sea cyclone was overestimated. Using SLHD, Tyrrhenian cyclone weakened and moved southwest while the Adriatic cyclone shifts inland.

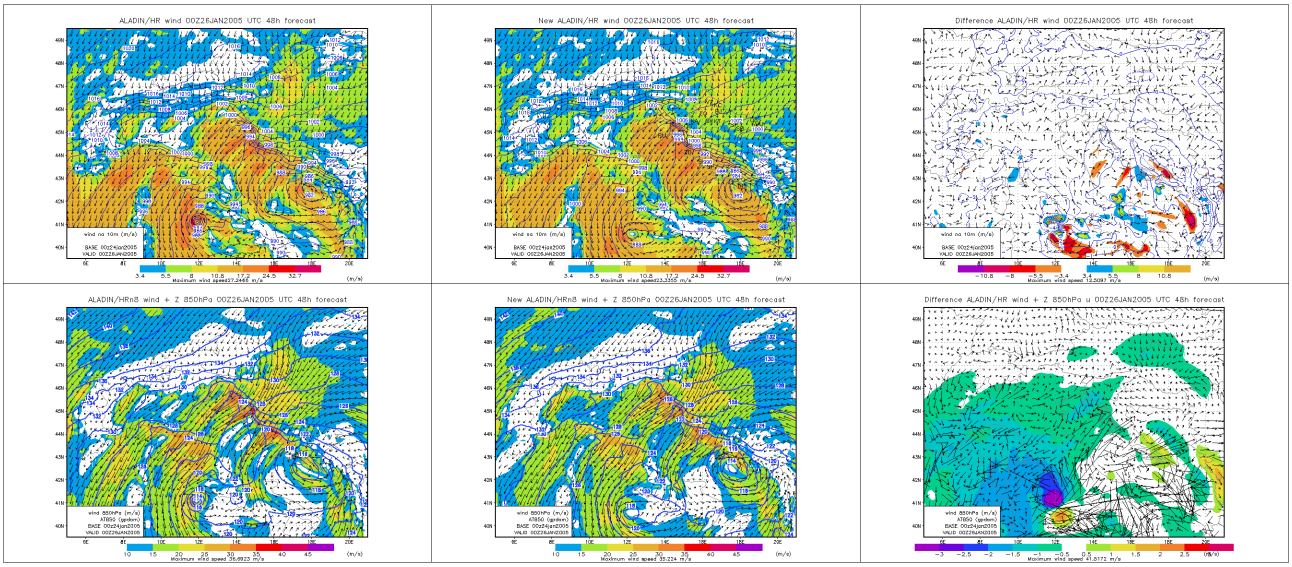

Figure 3. 10m wind and mean-sea-level pressure (top row) wind and geopotential at 850hPa (bottom row) obtained with numerical diffusion (left), SLHD (centre) and their difference (right), 48 hour forecast starting from 00 UTC 24th January 2005.

The results vary significantly depending on the type of the horizontal diffusion used in the coupling model. When the SLHD run is coupled to a purely numerical diffusion run, the Tyrhennian Sea cyclone is much weaker.

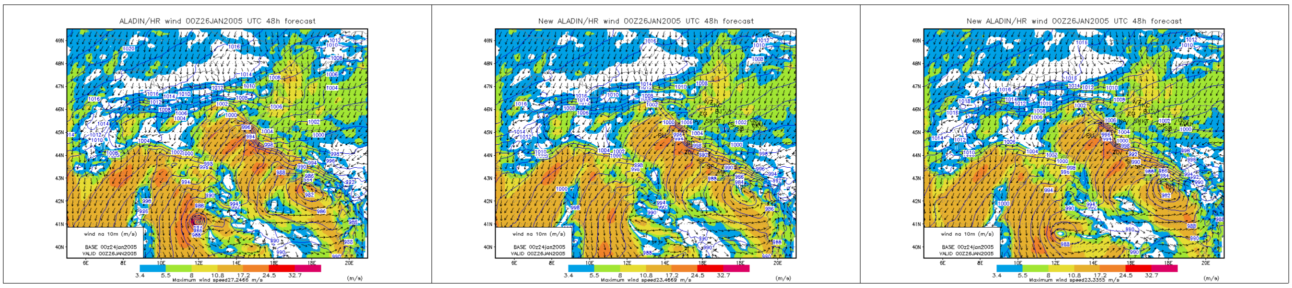

Figure 4. 10m wind numerical coupled to numerical diffusion (left), SLHD coupled to numerical diffusion (centre) and SLHD coupled to SLHD (right), 48 hour forecast starting from 00 UTC 24th January 2005.

4.3 Fog case

15th February 2004, Central Europe was under an anticyclone and most of the valleys were covered by fog. SLHD increases the amount of fog in Alpine valleys (border between Switzerland and Germany, and in Danube valley in Austria) since it reduces mixing between valleys and the air above.

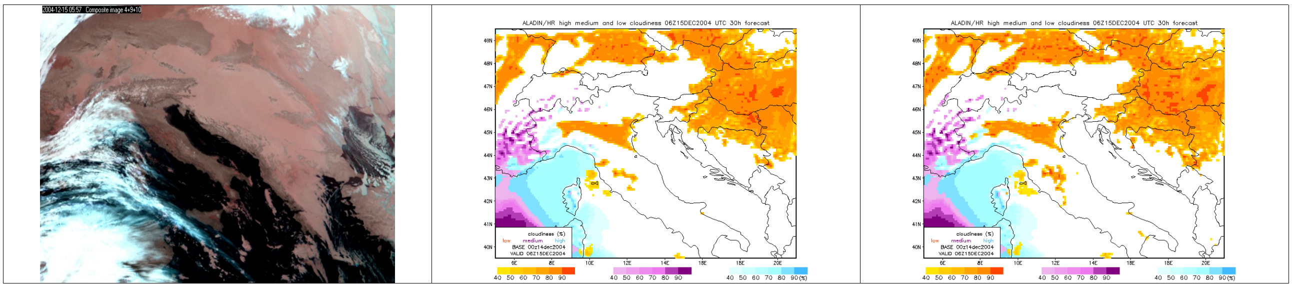

Figure 5. On the left is the Meteosat-8 RBG composite of channels 3.9, 10.8 and 12.0 µm for December 15th 2004, 06 UTC. Low, medium and high cloudiness, numerical diffusion (centre) and SLHD (right), 30 hour forecast starting from 00 UTC 14th December 2004.

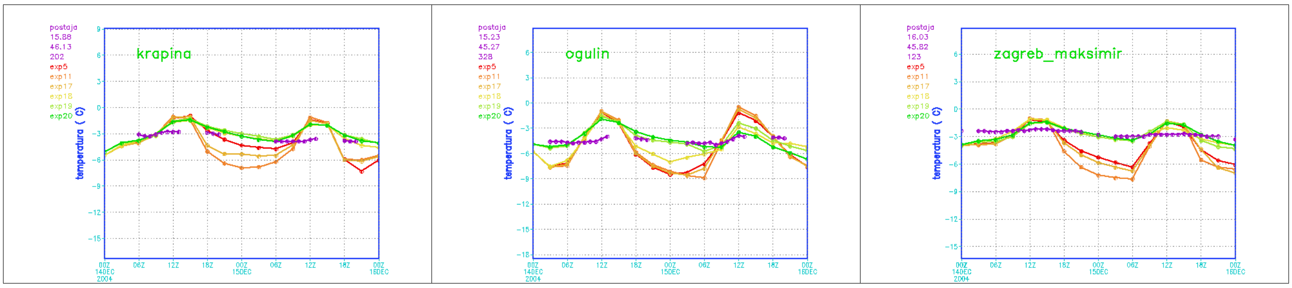

Figure 6. Comparison of the modelled 2m temperature evolution for 00 UTC run on 14th December 2004 with measured data from synoptic station (5-reference, 11-NER, 17-LRAUTOEV, 18-SLHD, 19-mean orography, 20-SLHD+mean orography).

5. Conclusions

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

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