Testing the new sub-grid scale orography representation on bura cases

Dunja Drvar, Ivana Stiperski, Martina Tudor and Vlasta Tutiš

Croatian Meteorological and Hydrological Service, Grič 3, 10000 Zagreb

E-mail: drvar@cirus.dhz.hr

1. Summary

The operational forecast of ALADIN model is satisfactory for the wind field, although the wind speed is sometimes overestimated. A modified subgrid-scale orography representation was introduced and tested. The envelope was removed and, to compensate for the loss of volume, changes in gravity wave drag parametrization were introduced. New orography representation resulted in slight enhancement of upstream and general decrease of downstream wind speed, as well as reduction of mountain wave amplitude.

2. Introduction

2.1 Envelope or not?

Representation of unresolved orographic effects is a difficult problem in numerical models, because of the large spectrum of processes involved. In the past few decades, the representation of subgrid scale orography has been attempted by different means. One of the methods is the enhancement of terrain by adding an envelope (see Wallace et al., 1983), while another one uses parametrization of gravity wave drag and lift. In ALADIN, both methods are implemented.

Although the envelope method is proved to give a better representation of the airflow over and around mountain ranges, it has limitations. The envelope artificially increases the mountain height, and therefore gives excessive precipitation on the windward side, stronger katabatic winds in the lee and overestimated amplitude of the mountain waves (see Bougeault, 2001). Because of the exaggerated terrain height, numerous measurements from the stations situated below the envelope are systematically rejected in data assimilation. Furthermore, studies of local behaviour of the ECMWF model near Pyrenees (Lott, 1995) and Alps (Clark and Miller, 1991) have shown that mountain drag is underestimated, and cannot be adequately substituted with the envelope. For these reasons, in a number of NWP models the envelope has been suppressed, and the gravity-wave-drag parametrization tuned to compensate for the lack of volume.

2.2 Experiments

The operational model results (AL25T1) are compared to the results from an experimental version of ALADIN, without the envelope and with the new gravity-wave-drag parametrization. In the operational model, envelope is obtained by adding the standard deviation of the sub-grid-scale orography to the mean height. Removing the envelope actually means lowering the mountain peaks as well as the valleys (see Fig 1). The difference is largest in the areas where the orographic variability is highest, e.g. on the mountain slopes.

With the reduction of the mountain volume, the pressure drag decreases, and has to be compensated by parametrization. The pressure drag is addressed by its two components: the lift (perpendicular to the flow), and the drag (parallel to it). In the experiment, the orographic lift is activated and gravity-wave drag is tuned.

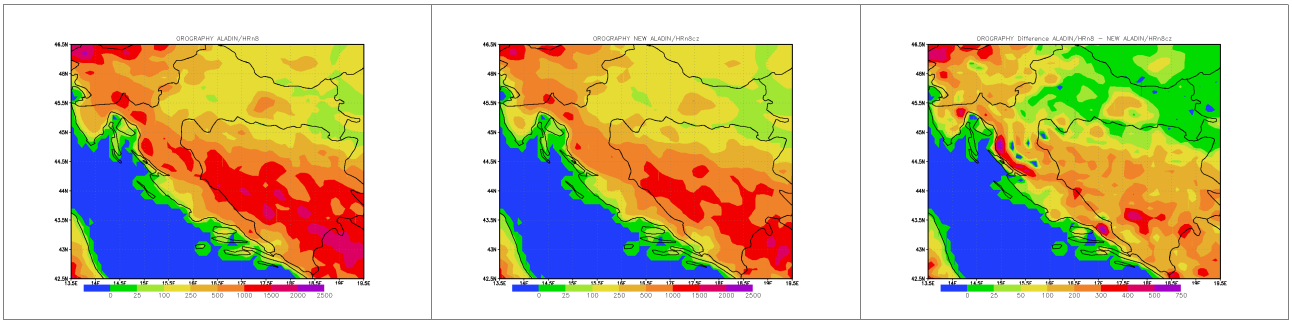

Figure 1. Orography in the operational (left) and experimental (centre) model version, and their difference (right).

2.3 Bura cases

One of the most interesting atmospheric features of the eastern Adriatic is orographically induced and forced bura wind. It is the outbreak of cold continental air over the Dinaric Alps, and its onset and intensity are strongly dependent on the wavelength and height of the orography. Therefore, an alternative version of ALADIN with the new sub-grid scale orography representation is tested on three bura cases.

Firstly, a case with generally weak bura was considered (3rd November 2004), when the drainage of air through the mountain-passes was induced by the pronounced difference in the air-mass characteristics in the inland and coastal part of the region. In addition, two extreme events of synoptically induced gale-force bura along the Adriatic coast (24th December 2003 and 13th November 2004) are studied.

3. Results

3.1 Weak bura

In the case of locally forced bura, blocking in the windward side of the mountain in the operational model is clearly seen (Fig 2), while the new version allows the drainage of the cold continental air to start earlier leading to weaker winds.

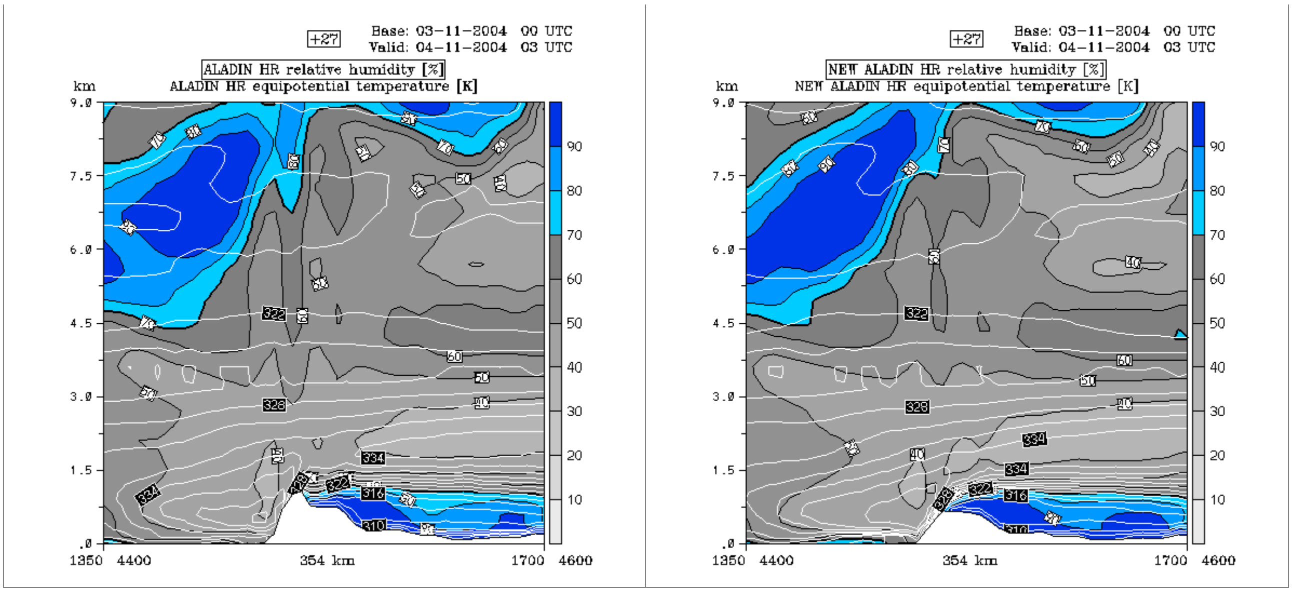

Figure 2. Vertical cross-sections perpendicular to the coastline from (13.5E, 44N) to (17E, 46N) of the modelled relative humidity with equivalent potential temperature in the operational (left) and experimental model version (right), 27 hours forecast starting from 00 UTC 3rd November 2004.

3.2 Strong bura

In cases with severe bura, the most obvious feature of the experiment results is the increase of the 10m wind speed on the windward and its even more pronounced decrease on the leeward side (Fig 3). The reason for this is found in the reduction of the mountain range height and the slope angle on one hand, and the increase of the pressure drag related to the orographic lift on the other hand. Due to the removal of the envelope, the pressure gradient across the coastal mountains is reduced. Moreover, the relative difference between the high peaks and low valleys is smaller, hence the canalised structure of the wind is less pronounced. However, there is no significant change in the wind direction.

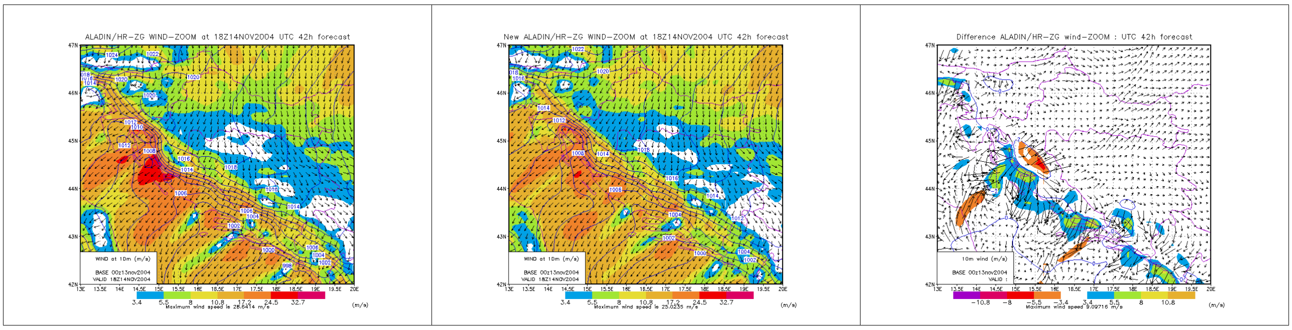

Figure 3. 10m wind in the operational (left) and experimental (centre) model version, and their difference (right), 42 hours forecast starting from 00 UTC 13th November 2004.

3.3 Severe bura

In the results of the operational model version, it is found that the artificially enhanced orography results in over-amplified mountain waves and unrealistic wave breaking (Fig 4). The lee wave reflects off the ground, therefore the wind maximum in the lee is closer to the surface, corresponding to the results found in the horizontal 10m wind fields. Results also show a pronounced orographically induced humidity maximum (cloudiness) near the mountaintop. As expected, in the experimental version the wave structure is smoothed. There is a more pronounced downstream momentum transfer leading to the different distribution of vertical motion induced by the obstacle. Therefore, the humidity maximum near the mountain peak is somewhat decreased, while the one in the middle troposphere is more pronounced and closer to the mountain.

4. Conclusion

Removal of the envelope and changes in the gravity-wave-drag parametrization result in stronger winds on the windward and generally weaker winds on the leeward side of the obstacle, as well as the reduction of the mountain wave amplitude.

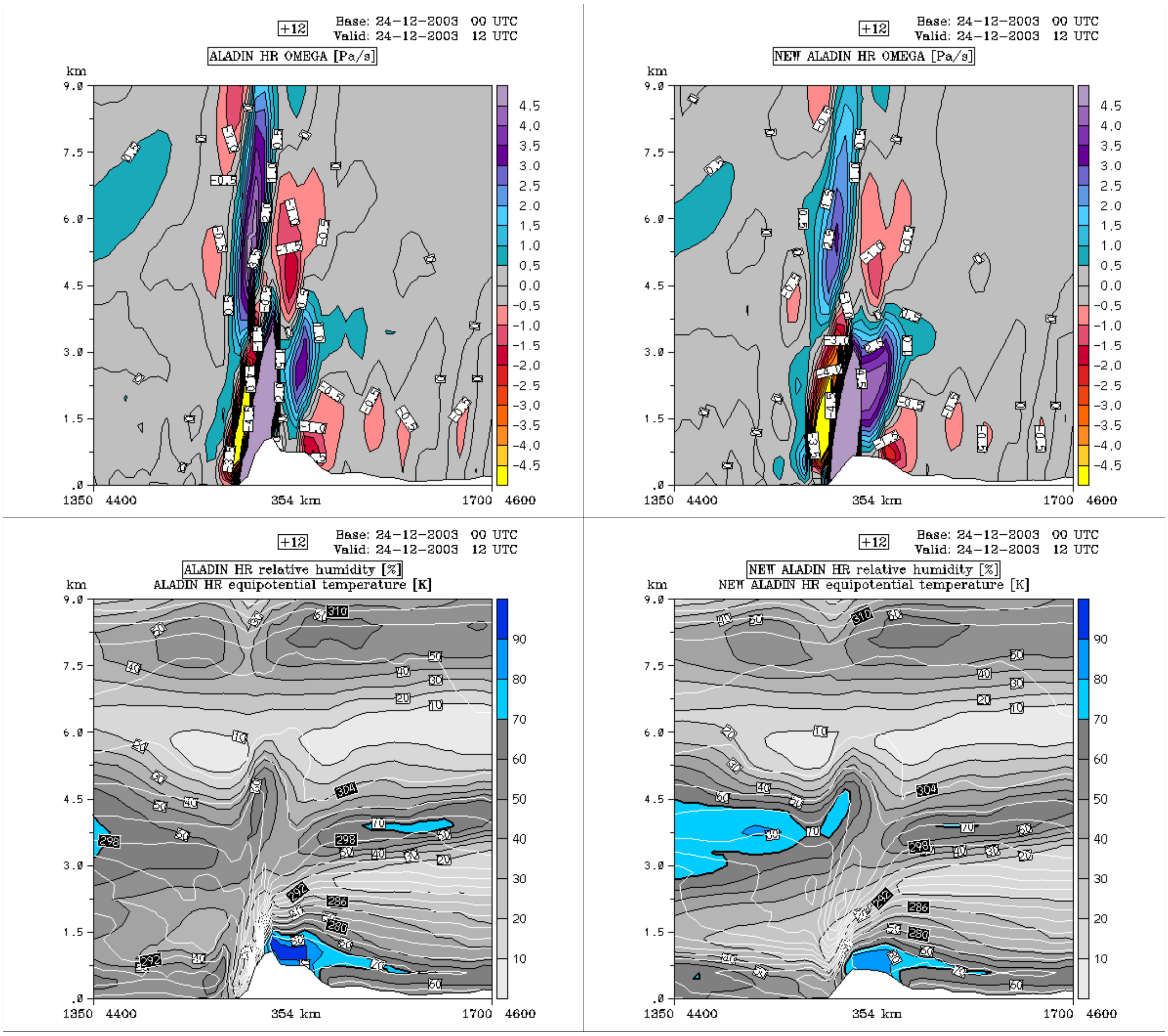

Figure 4. Vertical cross-sections perpendicular to the coastline from (13.5E, 44N) to (17E, 46N) of the modelled vertical velocity (top) and relative humidity with equivalent potential temperature (bottom) in the operational (left) and experimental model version (right), 12 hours forecast starting from 00 UTC 24th December 2003.

5. References

Bougeault, P., 2001: Sub-grid scale orography parametrizations, Proceedings, *ECMWF Key issues in the parametrization of subgrid physical processes,* 3-7 September 2001, pp.53-69.

Clark, T.L., and M. J. Miller, 1991: Pressure drag and momentum fluxes due to the Alps. II: Representation in large-scale atmospheric models. *Quart. J. R. Met. Soc.*, **117**, 527-552.

Ivatek-Šahdan, S., and M. Tudor, 2004: Use of High-Resolution Dynamical Adaptation in Operational Suite and Research Impact Studies. *Meteorologische Zeitschrift*, **13**, No. 2, 1-10.

Lott, F., 1995: Comparison between the orographic response of the ECMWF model and the PYREX data. *Quart. J. R. Met. Soc.*, **121**, 1323-1348.

Wallace, J. M., S. Tibaldi and A. J. Simmons, 1983: Reduction of systematic forecast errors in the ECMWF model through the introduction of an envelope orography. *Quart. J. R. Met. Soc.*, **109**, 683-717.

CONTENTS