IMPACT OF HORIZONTAL DIFFUSION, VERTICAL RESOLUTION, MICROPHYSICS, RADIATION AND CLOUDINESS PARAMETERIZATION SCHEMES ON FOG FORECAST IN VALLEYS

Martina Tudor

Croatian Meteorological and Hydrological Service, Zagreb, Croatia
E-mail : *tudor@mail.dhz.hr*

Abstract: This research is dealing with 2m temperature and cloudiness operational forecasts in inversion cases with fog and low stratus clouds. Several more or less computationally expensive options are tested. Different cloud schemes and cloud overlap assumptions play more important role than the modifications in the radiation scheme and microphysics. Representation of orography and more physical horizontal diffusion improve the forecast in valleys close to mountains.

Keywords: *fog, horizontal diffusion, radiation, cloudiness*

1. INTRODUCTION

Quality of the operational forecasts of 2m temperature and low cloudiness in a stable atmosphere with low-level inversion, low cloudiness and fog is often frustrating. There are different horizontal diffusion, several radiation and cloudiness schemes available in Aladin model that is used in the operational forecast. A simple microphysics scheme, with prognostic cloud water and ice, as well as rain and snow has been recently introduced in the model.

A study of a synoptic case marked by a strong temperature inversion, low cloudiness and fog in a wide valley in the inland part of Croatia that lasted for several days showed that even small changes, like different cloud overlap assumptions, can bring significant improvement in the forecast of low cloudiness and, consequently, the 2m temperature diurnal pattern. Surprisingly, more sophisticated radiation schemes do not always bring an improvement. Microphysics has a beneficial impact, but has less impact on the low cloudiness and fog forecast than the cloudiness scheme. Doubling the vertical resolution has a low impact in the case of thick layer of fog.

The correct forecast of fog and low stratus in narrow Alpine valleys is highly affected by the horizontal diffusion scheme used in the model. Common 4th order numerical horizontal diffusion is applied on model levels that follow orography, thus it is not purely horizontal and it is not physical. The significance of the physical horizontal diffusion increases with horizontal resolution as model levels become more tilted close to mountain areas and the horizontal mixing often occurs between "the valley" and "the mountain top".

The Semi-Lagrangian horizontal diffusion (SLHD) is based on the control of the degree of interpolation needed for the semi-Lagrangian advection scheme that depends on the local flow. In the case of fog in an anticyclone, use of SLHD increases the amount of fog in Alpine valleys.

2. METHODS

In the Aladin model version described in Ivatek-Šahdan and Tudor (2004) a cloud scheme adapted from Xu and Randall (1996) is introduced. The Ritter and Geleyn (1982) radiation scheme has been enhanced (Geleyn et al. 2005a, Geleyn et al 2005b) and there are other radiation schemes available (Bouysell at al. 2003) as FMR (Morcrette, 1989) and RRTM (Mlawer et al. 1987). The first radiation scheme is so cheap that it allows to be used every time-step and gradual development of cloud effects, while FMR and RRTM can be called only after several hours of forecast to allow a computationally efficient forecast. Different cloud overlap assumptions, like random, random maximum and maximum overlap have been tested in combination with modified vertical profile of critical minimum mesh averaged relative humidity producing a cloud.

Simple microphysics with cloud condensates and precipitation species as prognostic variables (Catry et al. 2007) is introduced. Vertical turbulent diffusion is also modified according to Geleyn at al (2006) and uses TKE as prognostic variable. Orography representation can be with or without envelope.

3. RESULTS AND DISCUSSION

A case of long lasting low clouds and fog that covered valleys in the wider Alpine area during the first half of December 2004 is used for one run covering 2 days. The 2m temperature varied very little during that period and showed no diurnal pattern. The model was run with 8 km horizontal resolution, 37 levels in the mass-based coordinate in the vertical and 327 seconds time-step (as the operational configuration).

The forecast most like the operational one at the time is the reference forecast (the experiment 1 – exp1). Different critical relative humidity profile has little impact. Random maximum overlap assumption when computing cloudiness significantly reduces the amount of clouds and even amplifies the diurnal variation of temperature as opposed to random overlap. The introduction of the Xu-Randall cloudiness scheme gives more clouds and improves the 2m temperature forecast.

The operational radiation scheme with Xu-Randall cloudiness parameterization and random overlap assumption produces the thickest low cloud layer that reduces the night cooling and heating during the day. It still shows signs of diurnal variation but is closest to the measured data. Enhanced radiation increases the amplitude of the diurnal variation of temperature, which gives worse forecast in this case. Radiation schemes need to be called at least hourly to allow fog to develop.

Use of SLHD increases the amount of fog in alpine valleys (Fig 1, bottom right), 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 mountain top instead in the valley. SLHD is more selective, the mixing is dependent on the wind deformation field, so in the situation with low wind speeds, the cloud stays in the valley.

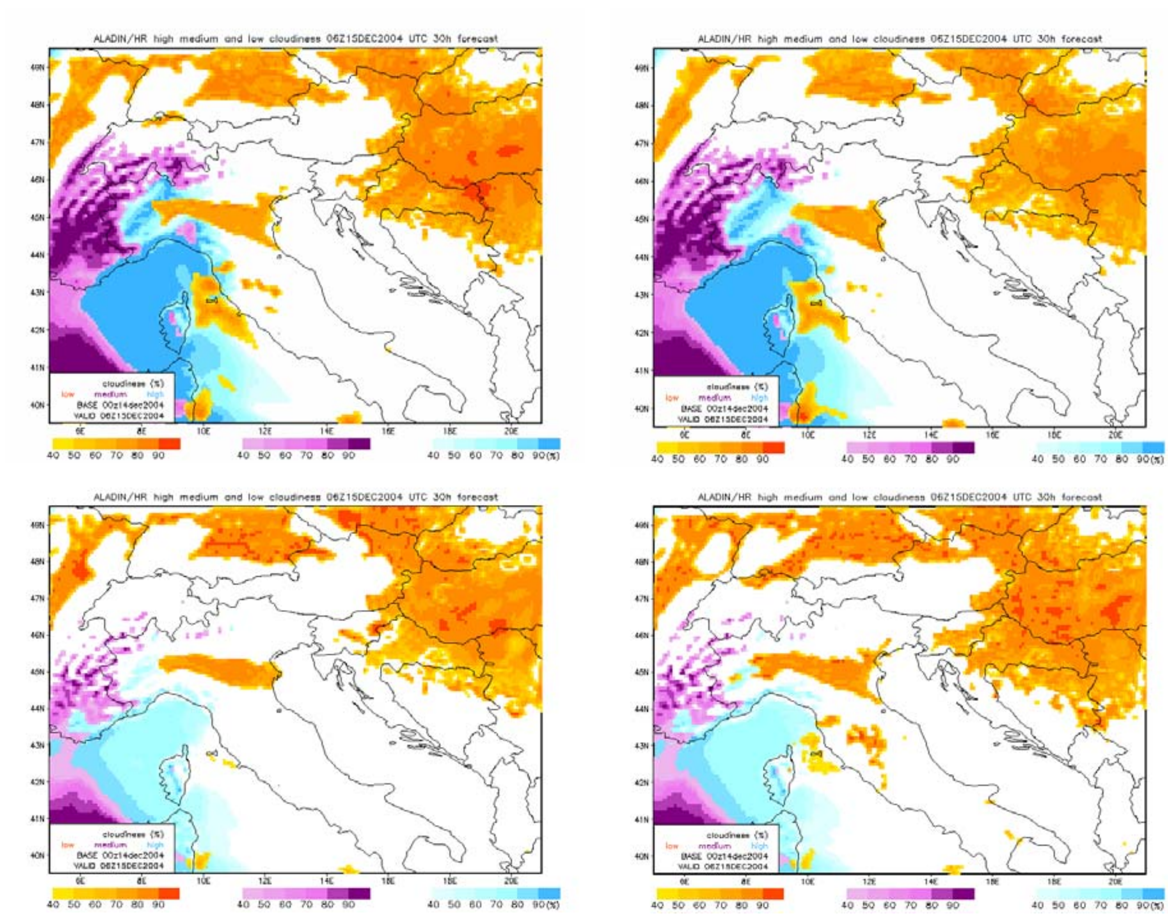

Figure 1: Low, medium and high cloudiness, with the operational Geleyn (top left), enhanced Geleyn (top right), FMR (bottom left) radiation schemes and 4th order numerical diffusion, operational radiation Geleyn with semi-Lagrangian horizontal diffusion (bottom right), all with Xu-Randall cloudiness and random overlap assumption.

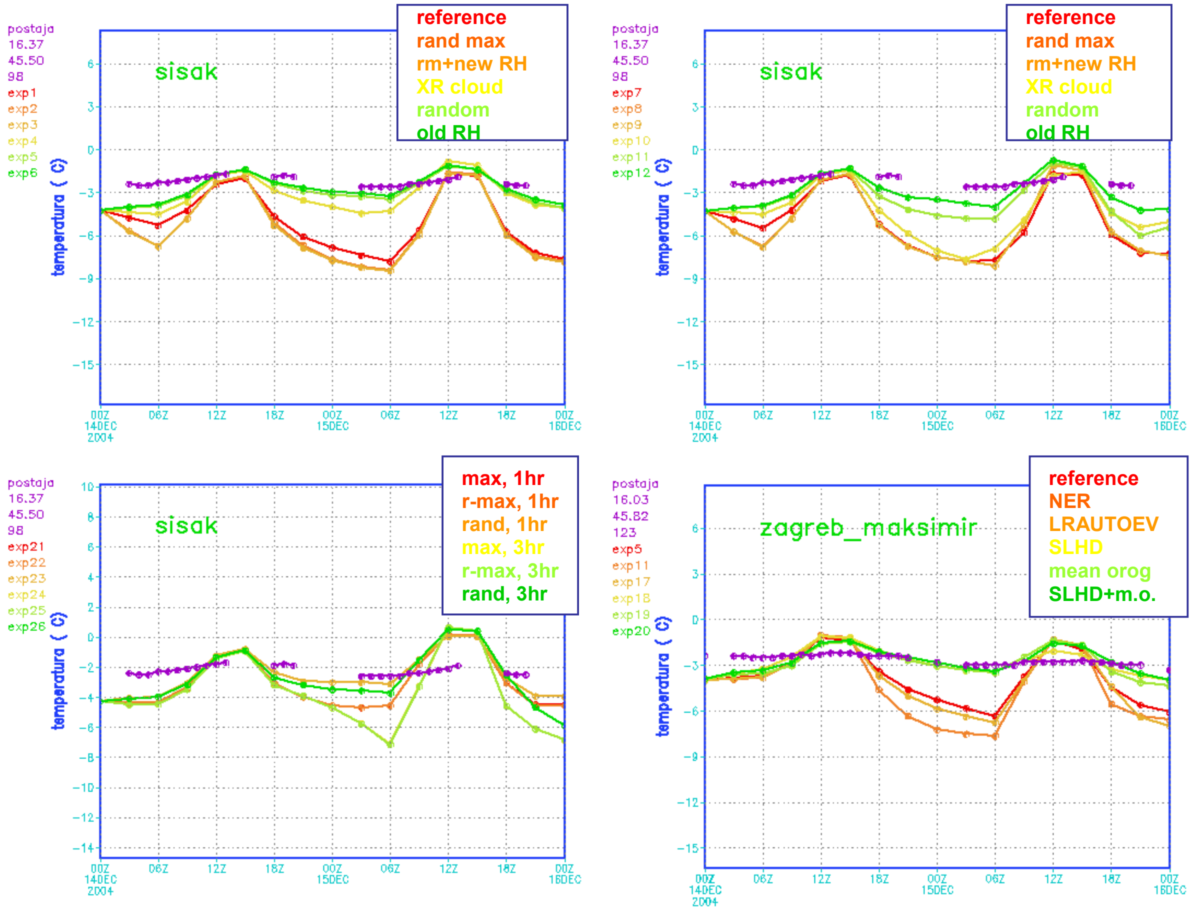

Figure 2: Comparison of the modelled 2m temperature evolution with measured data (dark purple) for Sisak and Zagreb Maksimir SYNOP stations, with the operational (top left), enhanced Geleyn (top right) radiation schemes for old cloud scheme, random overlap and old critical relative humidity vertical profile (red), random maximum overlap and new critical relative humidity vertical profile (orange), Xu-Randall cloudiness scheme (yellow) with random overlap (light green) and back to old critical relative humidity profile (green), with FMR radiation scheme (bottom left) maximum overlap and one hour frequency in radiation computations (red), random maximum overlap (orange), random overlap (light orange), maximum overlap and three hour frequency in radiation computations (yellow), random maximum overlap (light green) and random overlap (green). Bottom right panel is as for top left panel red line (red), top right panel red line (orange) and more complex enhancement (light orange) with 4th order numerical diffusion, operational radiation with SLHD (yellow), mean orography instead of envelope and numerical diffusion (light green) and mean envelope with SLHD.

Different representation of orography, with or without envelope, can lift certain areas below or above the fog layer and therefore have a significant impact on the correct forecast of the 2m temperature. Introduction of simple microphysics with prognostic condensates and TKE into turbulence scheme has a positive impact in the valleys and close to mountain slopes, but only in combination with SLHD since numerical diffusion would also mix the cloud condensate species from valley with the dry air on mountain tops. The persistent fog layer in this case was thick so increased vertical resolution has low impact, once the parameterizations are set to produce fog. Although fog is not a rapidly developing phenomenon, it seems necessary to compute radiation at least on an hourly basis to allow fog to develop in the model. Other phenomena, as well as transient fog cases might require new radiation coefficient every time-step.

Acknowledgements: *The author wishes to thank wide Aladin community who introduced a variety of modular choices that can be used in the model.*

REFERENCES

Bouysell, F., Y. Bouteloup, and J.M. Piriou, 2003: Changes in the Cloudiness Scheme and Preliminary Results with FMR and RRTM Radiation Schemes. *13th ALADIN workshop proceedings*, Prague (CZ), 24-28 November 2003.

Catry, B., J.-F. Geleyn, M. Tudor, P. Bénard and A. Trojakova, 2007: Flux-conservative thermodynamic equations in a mass-weighted framework. Tellus A, 59, pp. 71-79.

Geleyn, J.-F., and A. Hollingsworth, 1979: An Economical Analytical Method for the Computation of the Interaction between Scattering and Line Absorption of Radiation. *Beitr. Phys. Atmosph.,* **52**, 1-16

Geleyn, J.-F., P. Bénard and R. Fournier, 2005a: A general-purpose extension of the Malkmus band-model average equivalent width to the case of the Voigt line profile. Q. J. R. Meteorol. Soc., 131, pp. 2757-2768.

Geleyn, J.-F., R. Fournier, G. Hello and N. Pristov, 2005b: A new 'bracketing' technique for a flexible and economical computation of thermal radiative fluxes, scattering effects included, on the basis the Net Exchanged Rate (NER) formalism. WGNE Blue Book

Geleyn, J.-F., F. Vana, J. Cedilnik, M. Tudor and B. Catry, 2006: An intermediate solution between diagnostic exchange coefficients and prognostic TKE methods for vertical turbulent transport. WGNE Blue Book

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

Mlawer, E.J., S.J. Taubman, P.D. Brown, M.J. Iacono, and S.A. Clough, 1997: Radiative Transfer for Inhomogeneous Atmospheres: RRTM, a Validated Correlated-k Model for the Longwave. *J. Geophys. Res*., **102D**, 16663-16682

Morcrette, J.-J., 1989: Description of the Radiation Scheme in the ECMWF Model. *Technical Memorandum*, **165**, ECMWF, 26 pp.

Simon, A. and F. Vaña, 2003: False mesoscale cyclogenesis in the ALADIN model - Sensitivity study on initial conditions, physical parameterisations and horizontal diffusion, *Aladin Newsletter* **24**, available on http://www.cnrm.meteo.fr/aladin/newsletters/news24/news24-7.html

Tudor, M. and S. Ivatek Šahdan, 2002: MAP IOP 15 case study. *Croatian Met. Jour.,* **37**, 1–14

Vaña, F., 2003: Semi_Lagrangeovske advektivni schema s kontrolovanou difuzivitou – alternativni formulace nelinearni horizontalni difuze v numerickych predpovednich modelech, PhD, 133 pp.

Xu, K.-M., and D.A. Randall, 1996: A Semi-empirical Cloudiness Parametrization for use in Climate Models. *J. Atmos. Sci.,* **53**, 3084-3102