

Single-column HIRLAM tests of idealized cases related to CBR modifications proposed by KNMI and INM

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1 Introduction

The CBR turbulence scheme (Cuxart et al, 2000) has been tested in many different atmospheric boundary layer regimes performing reasonably well in general. Since its introduction in the HIRLAM reference system, a particular regime has shown a deficient performance of the scheme: the strong wind case, either with neutral or stable stratification. Some noise problems were corrected through the implicitation of the surface momentum fluxes (see previous note by Lenderink et al 2001) in the case of large u_* or very long timesteps. Nevertheless, a non realistic profile of the wind velocity was found in the lower model levels in the case of strong winds. Two different approaches were tried to overcome the problem, developed independently at KNMI and at INM, starting from the reference CBR. We will show in this short note some results in single column mode of both modifications against the reference CBR version.

- CBR_KNMI modification: (Lenderink and de Rooy, 2000), based on a modification of reference CBR mixing length calculation (Bougeault and Lacarrère(1989), hereon BL89)
- CBR_INM modification: A change from reference CBR scheme was proposed, modifying c_u coefficient from a constant value to a value dependent on the local Richardson number($c_u(Ri)$).

2 CBR_INM proposal

Since CBR_KNMI is documented in Lenderink and de Rooy (2000), just a short description of the INM proposed modification is made. c_u is a part of the whole momentum exchange coefficient parameterization of momentum fluxes:

$$\overline{w'u'} = -c_u L e^{1/2} \frac{\partial u}{\partial z}$$

The original value of this parameter is $c_u = 0.067$, physically based from laboratory studies in non-convective conditions. In the HIRLAM implementation, for dry convective conditions, best verification scores were found using $c_u = 0.4$, which is an empirical value found previously in a former implementation of a similar scheme in the french Peridot model. Unfortunately, this value is too strong when mechanical mixing is the only agent acting, and

the momentum mixing is therefore too strong, leading to a too well mixed profile in the case of significant wind. In consequence, it was decided to use again $c_u = 0.067$ as the base value but letting $c_u = 0.4$ to be active in dry convective conditions. This has been made through the use of a linear interpolation between the two extreme values as an initial try. This function may be improved in the future.

$$R_i = \frac{\frac{g}{\theta_v} \frac{\partial \overline{\theta_v}}{\partial z}}{\left[\left(\frac{\partial \overline{u}}{\partial z} \right)^2 + \left(\frac{\partial \overline{v}}{\partial z} \right)^2 \right]}$$

- Unstable conditions (convective): $R_i \leq -1 \Rightarrow c_u = 0.4$
- Stable conditions: $R_i \geq 0.25 \Rightarrow c_u = 0.067$

A more physical and complete justification of these modification could arise from the pressure perturbation terms not considered on TKE evolution equation. They are usually neglected, but they might play an important role in these cases. We assume that the introduction of these terms in the original second order equation could lead to the modification of the momentum exchange coefficient (to be done).

In this proposal, the BL89 mixing length is unmodified, to not alter the physical behaviour and interpretation of this length.

3 Results from 1D HIRLAM idealized cases

Four idealized case studies were done, representing different schematic boundary layer situations. No other physical parameterizations are activated other than turbulence and surface schemes. Large scale external forcings are prescribed, and 40 levels are use in these runs.

- Convective case with some shear (Ayotte case: Ayotte et al,1996) (Run length= 4h, $\Delta t = 90s.$, AYO form here)
- Convective case. A modification of previous case, but chosing zero wind initial profiles to study just thermal processes. Run length= 4h, $\Delta t = 90s.$ (CBL)
- Neutral case with shear (Leipzig case, from Nielsen and Sass, 2000, LEI) Run length= 36h, $\Delta t = 300s.$
- Intermittent turbulence in a thermally stable boundary layer (based on SABLES observations campaign (Cuxart et al (2000), SAB) Run length= 6h, $\Delta t = 90s.$

We will show mainly results from LEI case, because the case is very similar to the problem cases observed in the Reference system. Unfortunately, no observational data are available

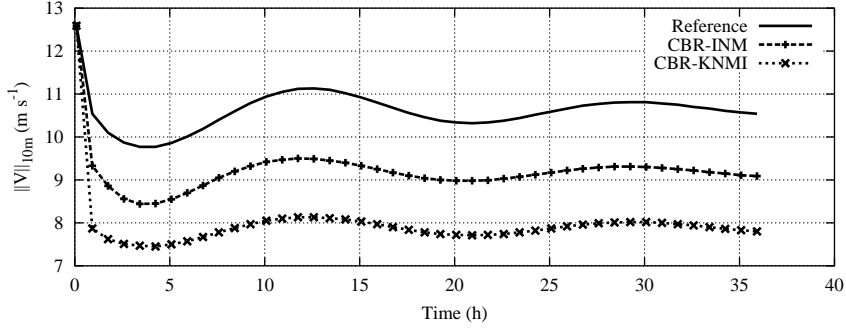


Figure 1: Wind timeseries of LEIPZG case

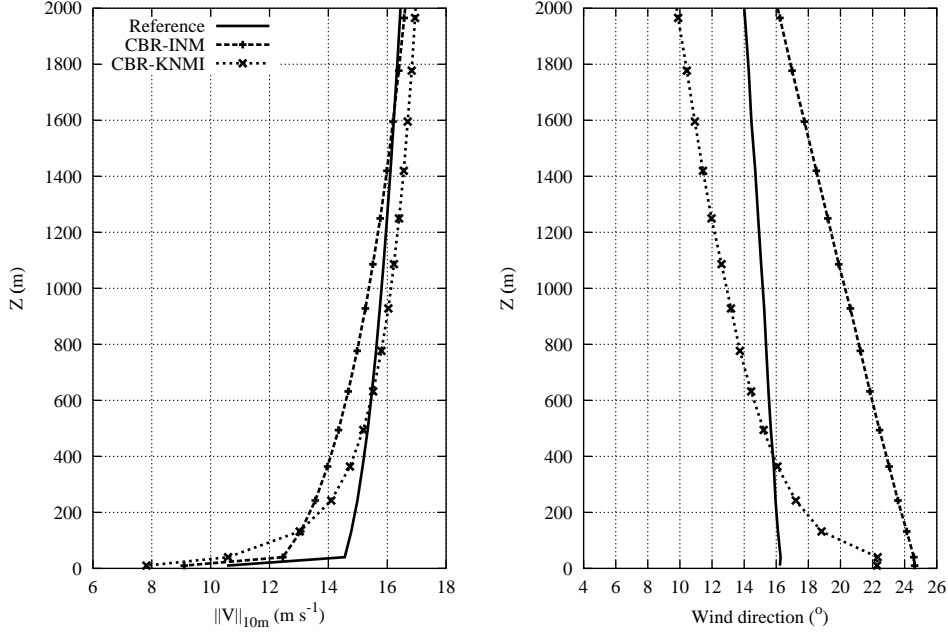


Figure 2: Wind speed profiles at last hour (h35-h36), LEIPZIG case

to compare results of 1D simulations for LEI or AYO cases. Nevertheless, we can inspect if the proposals act in the correct way towards less mixing of momentum, at least qualitatively.

In figure 1 timeseries of wind speed are shown, for LEI case. Both proposals give lower values of 10m wind module ($\|V\|_{10m}$) throughout the simulation compared to Reference operational CBR scheme results. CBR_KNMI gives lower values than CBR_INM, although we can't say which results is better. But it can be stated that both proposals reduce wind close to surface, as it was expected, compared to too high reference results. Last hour averages (h35-h36) of vertical wind profiles are shown on figure 2. It can be seen that both modifications show a less well mixed wind profiles close to the ground, consistent with timeseries seen before. Both proposals show a higher gradient close to the ground, and also a higher turn of the wind at those levels, both than Reference results. Again, CBR_KNMI gives higher reduction of wind and higher turn of the wind.

Similar features are seen from AYO case, although with in a lesser degree (figures 3 and 4).

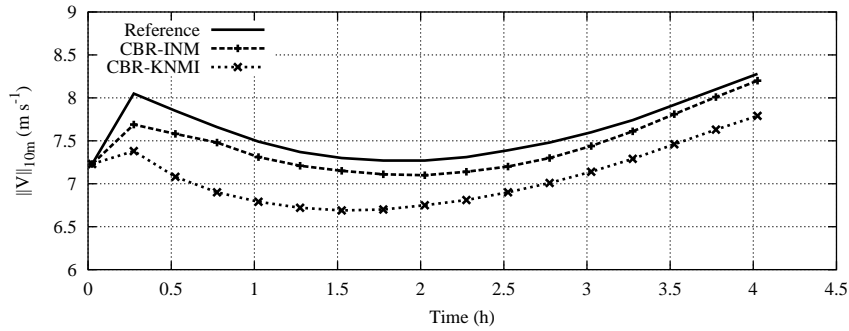


Figure 3: Wind timeseries of AYOTTE case

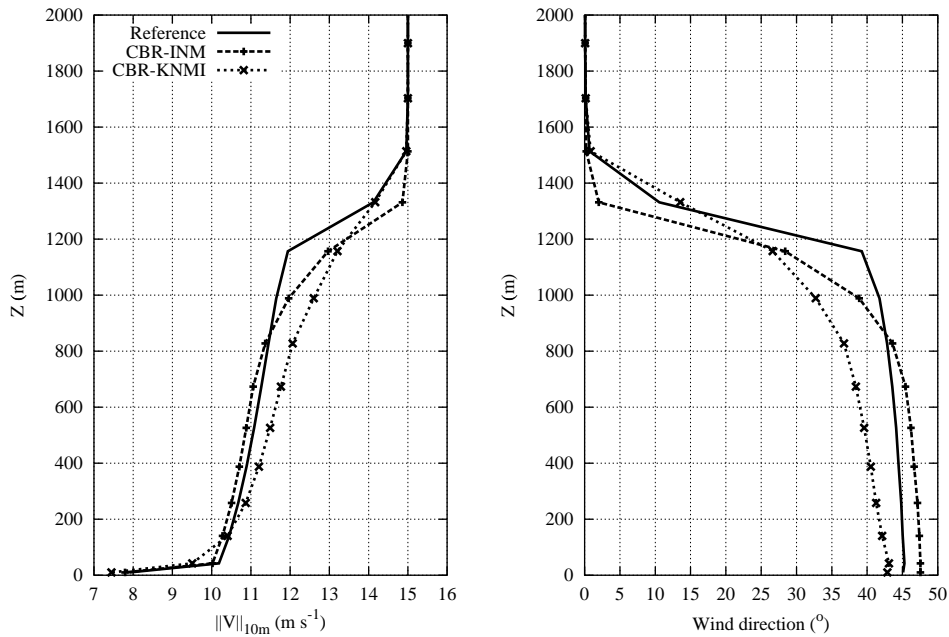


Figure 4: Wind speed profiles at last hour (h3-h4), AYOTTE case

CBR_KNMI shows a more clear reduction of wind speed both seen in timeseries and last hour averaged vertical profiles. CBR_INM shows only a small reduction when compared with reference. In CBR_INM proposal this is due to the basically convective driven situation, and shear only modifies slightly c_u values from 0.4 convective values. The present test just shows that both proposals tend to give lower values of the near-the-surface wind speeds, but cannot say which one is closer to the good behaviour. A more elaborated experimental validation would be of major interest. However, in the meantime, parallel runs can give hints on whether the modifications are pointing in the good direction.

4 Conclusions

Both proposals show a less well mixed state for idealized sheared situations than reference CBR scheme. Other idealized cases not mainly shear driven (not shown) indicate that results for other situations are not degraded compared with reference CBR. CBR-INM modification is still under improvement, since dependance of c_u of R_i is under study to make it more physically based, and to be closer to observations and verifications. As long as this is just a partial study in the comparison of both proposals to modify CBR, complementary work has been done. Parallel runs for a winter period (Järvenoja, 2001) and comparison against observational data (de Rooy, 2001) have been made. They support that both proposals improve high wind situations in almost neutral state, related to reference CBR. Nevertheless, parallel runs for other periods are being performed at INM, to have a more complete view of the effects of the modifications.

5 References

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