Introduction

The aim of the study was to find appropriate formula and setting for the mixing length in the ALARO-3MT model. The definition of the mixing length is bounded with the parameterization and tuning of the Planetary Boundary Layer (PBL). Therefore the sensitivity of the model on the PBL setup was also evaluated. First part of the work (looking for appropriate formula) was done in single column model with data from GABLS2 experiment. This enabled to compare the scheme proposals with observations and with different parameterizations (e.g. 1.5 order closure turbulence scheme tested in the ARPEGE model). An idea of implementation of Bougeault-Lacarrere kind of formula for mixing length was tested. Besides other qualities of this scheme (very suitable for convective cases and mixed PBLs), the possibility of having compatibile mixing length definition with ARPEGE and future AROME model was also taken into account. Simpler schemes for stable stratification used in the HIRLAM model (based on the ratio of the turbulent kinetic energy and Brunt-Väisälä frequency were also studied).

The results of the work are three proposals for mixing length parameterizations which were also evaluated on certain sensitive case studies in early ALARO -3MT 3D model version (September 2006). The document is organized in 7 parts. The first describes the tuning of the PBL height and the second the test of the mixing length parameterization in single column model. Third part contains proposals on adjustments of the original mixing length parameterization dependent on the PBL height. The fourth and the fifth sections are related to merging of the existing formulation of the mixing length with the Bougeault-Lacarrere type and HIRLAM type, respectively. Case studies with 3D model are described in section 6. Conclusion is given by section 7.

1. Tuning of the Ayotte PBL height

In the Ayotte kind of parameterization (Ayotte, 1996) the PBL height is estimated as a height, where the local value of the virtual potential temperature $\theta_v(z)$ first time overlaps a mean $\overline{\theta_v}(z)$ computed from the surface by a specific amount χ_0:

$$h_{PBL} = \min(z), \text{ so that } \quad \theta_v(z) \geq \chi_0 + \frac{1}{z}\int_0^z \theta_v(z)\,dz$$

Tuning of χ_0 is provided by parameter GPBLHK0 in the NAMPHY0 namelist part of the cy29t2 version of ARPEGE/ALADIN model. Current value used for GPBLHK0 is 0.25 K (see the report of Piriou and Geleyn, 2002).

The computation of the PBL height can be symbolically written:

$$h_{PBL} = \int_0^\infty f(\theta_v')\,dz\,,$$

where

$$\theta_v'(z) = \theta_v(z) - \frac{1}{z}\int_0^z \theta_v(z)\,dz$$

The variable $\theta_v(z)$ is modified with respect to wind-shear. This parameterization was introduced by Martina Tudor (in the ACCLPH routine, not optional). The formula for the modified $\theta_v(z)$ at model level l ($\theta_v^*(z)$ or ZTHETAVS in the code) yields:

$$\theta_v^*(l) = \theta_v^*(l+1) + \Delta\theta_v - \widetilde{\theta}_v \left|\frac{\Delta\vec{v}}{\Delta\phi}\right| |\Delta\vec{v}|$$

The aim of the GPBLHK0 tuning was to test the sensitivity of the diagnosed PBL height in GABLS2 experiment (Svensson, 2005, Svensson and Holtslag, 2006, and Cuxart et al., 2005). It was expected that different setup of the parameter can lower the PBL profile, which is currently systematically higher with respect to certain reference experiments (provided by Eric Bazile, Mètèo France).

First tests were using a version of the Ayotte PBL height parameterization, which is adjusted with respect to the wind shear (see above, this parameterization was denoted as "MaTu"). The experiments for this case are called:

EBREF – reference experiment of Eric Bazile
ASREF / GPBLHK0 = 0.25
HK0p5 / GPBLHK0 = 0.5
HKp12 / GPBLHK0 = 0.12
HK0p0 / GPBLHK0 = 0.001   (note: it is not possible to use a value of 0)

The first figure shows that the diagnosed PBL height is sensitive only in some parts of the model run (between 10 and 20 hours of computation). However, comparing with reference experiment, the PBL height evolution is very different, showing deep oscillations. The tuning of GPBLHK0 to smaller values makes the decrease of PBL height steeper in the sensitive parts of the computation.

More reasonable is the evolution of PBL height with the Ayotte parameterization, which does not use the wind shear adjustment (this parameterization is signed as "base"). The GPBLHK0 tuning to smaller values causes steeper transitions of the PBL height (this behaviour is closer to the reference experiment). However, the PBL height remains systematically higher than by EBREF and still shows certain oscillations and fibrillations (Fig. 2).

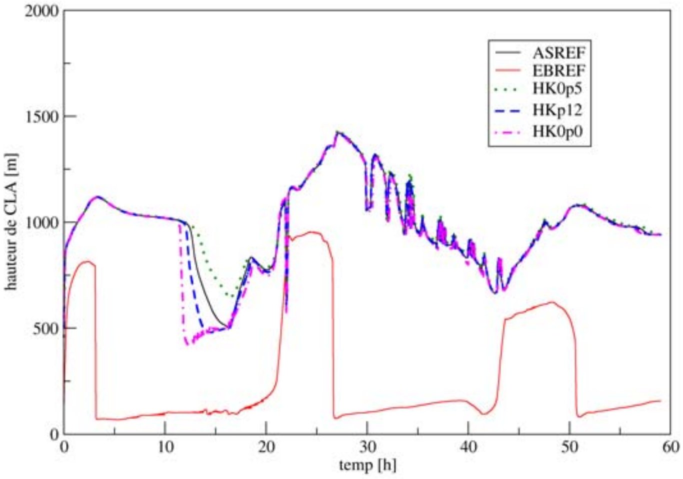

Figure 1: Diagnostic PBL height evolution according to GPBLHK0 tests using the MaTu shear-linked parameterization.

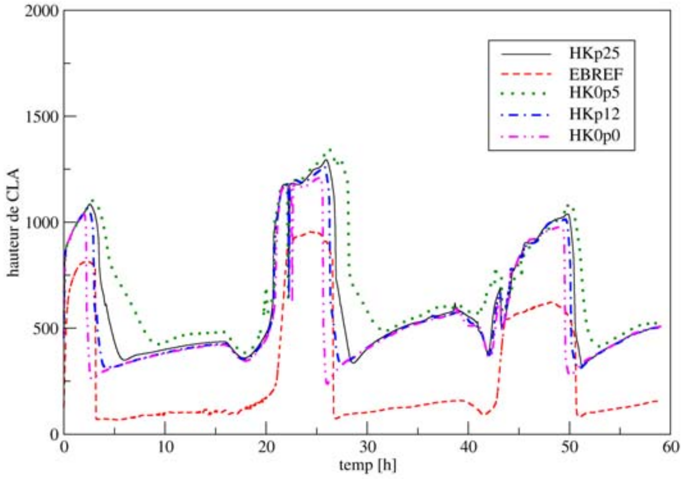

Figure 2: As in Figure 1 except for the “base” experiment without shear-linked adjustment.

It is interesting to compare the methods of PBL height computation used in the ARPEGE/ALADIN physical parameterization with the one diagnosed particularly for the GABLS2 case (GABLS2_DIAG, which is the same as in the above EBREF experiment). The comparison included the “MaTu” shear-linked parameterization of the PBL height, the “base” experiment without this adjustment and the Troen and Mahrt (hereafter “TM”) kind of parameterization with lower limit for the PBL height (XMINLM parameter) equal to 50 meters (Figure 3).

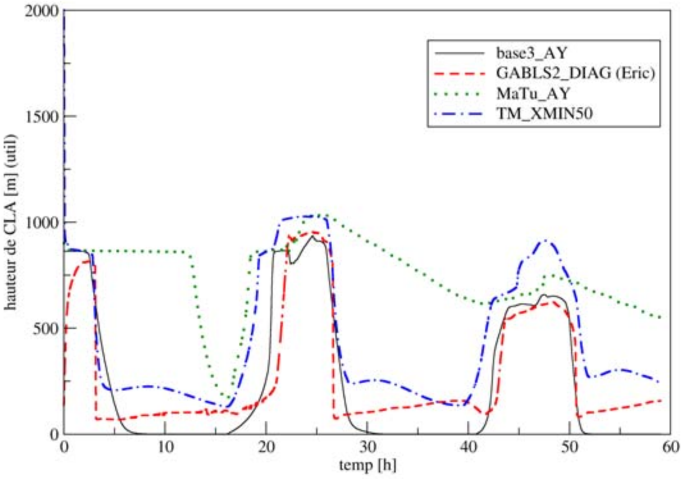

Figure 3: Comparison of the PBL height parameterizations with the diagnostic PBL height in the GABLS2 experiment.

It is possible to see that in the "MaTu" kind of parameterization, the PBL height remains almost constant in the first 10 hours of the run, showing further not realistic daily course of PBL height. Nevertheless, the MaTu shear-linked modifications are important in the 3-D model, above all in situations with strong baroclinicity and wind shear. On the other hand, the "base" Ayotte type parameterization shows exaggerated daily course of the PBL height (drop of the PBL to the surface seems to be not realistic).