4. Merger of the empirical mixing length type with BL89 parameterization

The vertical profile of the mixing length used in the classical ALADIN model physical parameterization (GC05 and GCS06 included) is based on observational studies and on the knowledge of the typical variation of eddy viscosity in the boundary layer (O` Brien, 1970). Further, the functions prescribing the mixing length expect smooth transition between the surface layer (linear increase) and the PBL (nonlinear behaviour). Despite of the current PBL height dependency, these formulations might be considered as empirical (although, this is not a reason to underestimate this way of parameterization).

As will be shown later, in 3-D experiments, the turbulence simulation and TKE production with empirical mixing length in stable planetary boundary layer is quite satisfactory. Moreover, empirical formulas are well tunable and designed for the K-type parameterization and for the computation of the exchange coefficients. On the other hand, there are situations, when significant turbulence appears in the upper troposphere (e.g. CAT in presence of strong wind shear below the jet axis), where the values of mixing length and exchange coefficients usually decrease. This cannot be solved by simple retuning of the mixing length profile, because the mixing length (and TKE production) would change systematically everywhere. Similar problems can appear also in cases with convection (well mixed PBL profiles) or in unstable layers capped by inversion that can be better described by BL89 parameterization. A merger of the two approaches could benefit from positive behaviours of both parameterizations.

As mentioned before, the separate use of the empirical mixing length for K-coefficients computation and BL89 mixing length for the TKE equations is neither ideal, nor physical solution. The empirical mixing length might be rather considered as a first guess, as a feature, which typically occurs in a standard troposphere. The BL89 mixing length parameterization can be treated as additional information about presence of intense turbulence (particularly with respect to levels above the PBL top). The experiments with 1-D model show that the BL89 mixing length can reach several times higher maxima comparing to values allowed by 1st order closure empirical schemes. Thus, a reasonable rescaling of the BL89 contribution seems to be necessary to avoid further increase of the mixing length that could provide non-realistic exchange coefficients and fluxes.

Taking into account the above mentioned requirements and considerations, the desirable formula can be expressed as follows:

$$l_{m/\theta} = l_{0_{m/\theta}} + k_{m/\theta}\left(l_{BL89} - l_{0_{m/\theta}}\right),$$

where $l_{0_{m/\theta}}$ denotes the empirical formula for the mixing length and l_{BL89} is the Bougeault-Lacarrère parameterization (mixing length for momentum and enthalpy are in general not distinguished by BL89, although this possibility will be kept in the code). The parameter k should have values between 0 and 1 (fully empirical scheme and full BL89 scheme, respectively). Further, this factor is vertically discretised. For the time being, a restriction is applied, allowing only positive changes with respect to the first guess ($k_{m/\theta}\left(l_{BL89} - l_{0_{m/\theta}}\right) \geq 0$).

The vertical discretisation of parameter k is done by empirical function:

$$k_{m/\theta} = \beta^* + \frac{2\left(\frac{z+z_{0/\theta}}{3H}\right)\lambda^*}{1+\left(\frac{z+z_{0/\theta}}{3H}\right)^{c^*}},$$

Where β^* and λ^* prescribe the minimum and maximum asymptotic value for the k parameter, H is one third of the height, where the function reaches its maximum (the units of this height are meters). Recommended tuning is shown by table 2.

Parameter	ALMKEN	BLMKEN	AFCEN	ALMZH
Denotation	λ^*	β^*	c^*	H
Value	0.4	0.1	3	1500

Table 2: Setup of parameters for defining the vertical profile of the k parameter used in the merged empirical – BL89 scheme.

The setting of the k profile was done to increase the influence of BL89 scheme above the PBL in situations, where mechanical production of TKE can be expected (this selection was done as a consequence of certain 3D tests described later). Hence, the maximum of the function is reached at height about 4000 m (Figure 20).

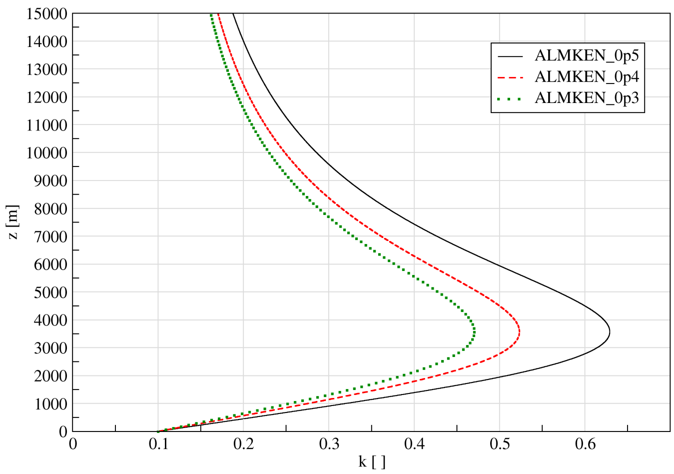

Fig.20: Tuning of the k function for different values of ALMKEN (λ^*= 0.5, 0.4 and 0.3, respectively). The surface and the asymptotic value at the top of the atmosphere (β^*) is 0.1.

The GCS06 parameterization was used as a first guess in 1-D experiment (assigned as LMBL) with the above proposed scheme on GABLS2 case. The resulting mixing length profile is qualitatively very similar to the BL89 simulation, moreover, some noisy features between 25 and 45 hour of the computation are suppressed (Fig. 21).

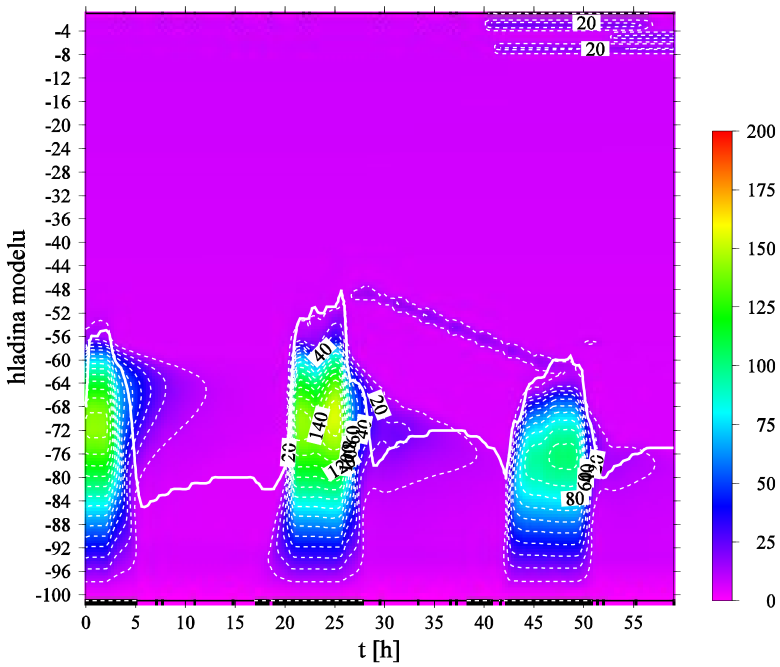

Fig. 21: As in Fig. 17, except for the merged GCS06 and BL89 parameterization (experiment LMBL)

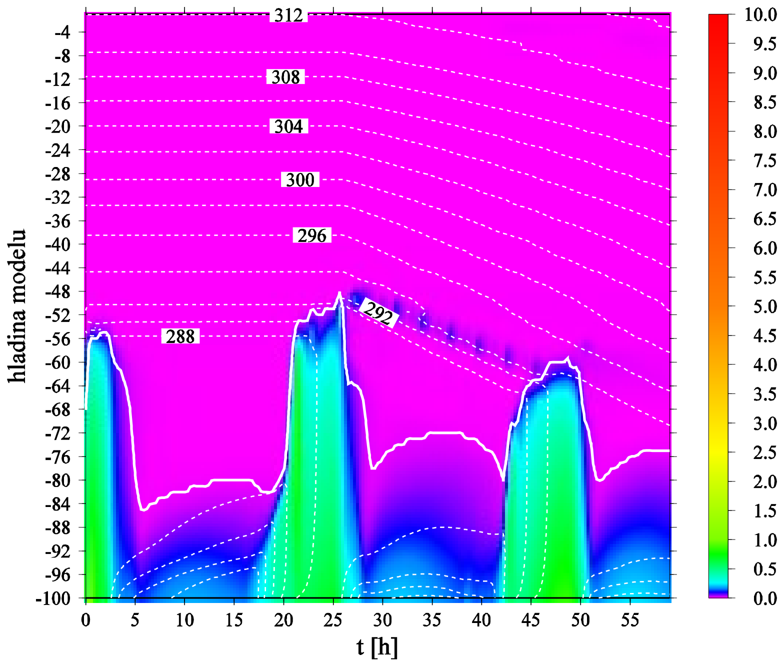

Fig. 22: As in Fig. 18, except for the merged GCS06 and BL89 parameterization

The TKE evolution seems to be similar to the GCS06 test, except for the night PBL, where the values of TKE are bigger (Fig. 22). The course of the PBL height is approaching the GCS06 evolution in the first half of the run and it is systematically better comparing to the GC05 simulation with ALMAV=400 or to fully applied BL89 scheme (Fig. 23).

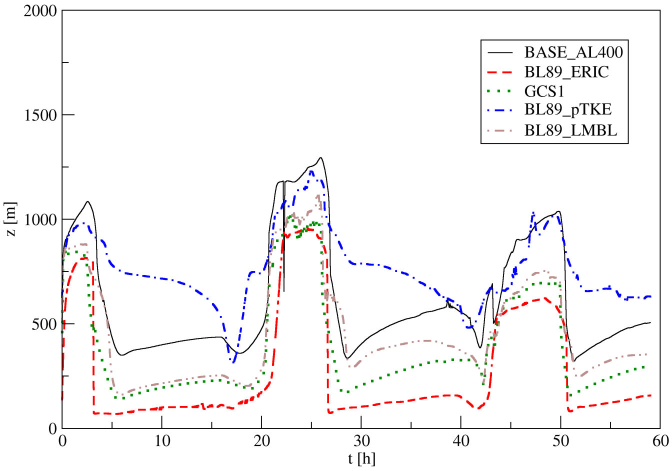

Fig. 23: GABLS2 diagnostics of the PBL height and comparison of the reference BL89 parameterization (ERIC, dashed line), GC05 scheme with ALMAV=400 (solid line), GCS06 modification (dotted), fully applied BL89 parameterization (dash-dotted) and merged GCS06-BL89 mixing length parameterization (dash-double dotted line). The setup of the latter parameterization is the same as in tables 1a) – c) and 2.