GABLS experiment, Sodankylä comparison with RCR: some benefits for ARPEGE/ALADIN ?

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1. INTRODUCTION

The GABLS experiment (GEWEX Atmospheric Boundary Layer Study) provides a clear framework for 1D and LES intercomparison on a stable boundary layer (SBL) (Holtslag, 2003). It is an Artic case, studied by Kosovic and Curry (2000) , the single-column model is driven by an imposed geostrophic wind, with a given surface cooling rate. The roughness length is specified, the radiation scheme is switched off, therefore only the vertical diffusion is active.

The ARPEGE/ALADIN model is not able to reproduce correctly the Ekman spiral and the low level jet does not exist due to the excess mixing in the SBL on the wind (Fig: 1) and the temperature. The PBL parametrization, based on Louis et al (1981) , computes the exchange coefficient as a function of a mixing length, the wind shear and the Richardson number Ri.

$$K_m = l_m l_m \mid \frac{\partial V}{\partial z} \mid F_m(Ri^{'})$$

$$K_h = l_m l_h \mid \frac{\partial V}{\partial z} \mid F_h(Ri^{'})$$

The mixing length profile (l_m, l_h) is constant in time and in space. $Ri^{'}$ is a Richardson number function of a critical Richardson number Ri_c, l_h and z.

2. THE MODIFICATIONS

Firstly, a new coefficient k has been introduced in the function $F_{m/h}$ to reduce the mixing in stable condition (Fig: 1). Secondly, the PBL height (PBLH) is now computed following the Troen and Mahrt (1986) proposal and used to compute the mixing length. For the temperature and the humidity, the mixing length is a cubic function which verify $\frac{dl_h}{dz} = k$ for $z \to 0.$, for $z \geq PBLH \Rightarrow l(z) = Cste$. For the momemtum part the operational function (l_m) is used but, now, depends on the PBL height. The new mixing lengths are shown in figure 2 for two PBL height 1000m and 4000m (dotted and dashed line resp., the full line is the operational version).

The modified version on the GABLS case improves the vertical profile of the wind speed with a maximum near the SBL top as seen in the LES (Fig: 1). The friction velocity (u^*), the Monin-Obukhov length (L_{MO}) and the surface angle for the wind direction are improved (Tab: 1). However, it is not yet perfect for the Ekman spiral and the PBL height. The Prandl number is also overestimated by a factor 2 or 3 compared to the value provided by the LESs.

	PBLH	$\overline{w'\theta'}$	u^*	L_{MO}	Surface angle
Oper	383m	-0.013	0.34	204	23
Modified	333m	-0.014	0.31	142	29
ARPEGE TKE	132m	-0.010	0.24	99	34
LES	[160, 195]	[-0.01, -0.013]	[0.26, 0.30]	[120, 170]	[32, 38]

Table 1: 1D simulation with the prescribed vertical resolution $\delta z = 6.25m$ and $\delta t = 30s$

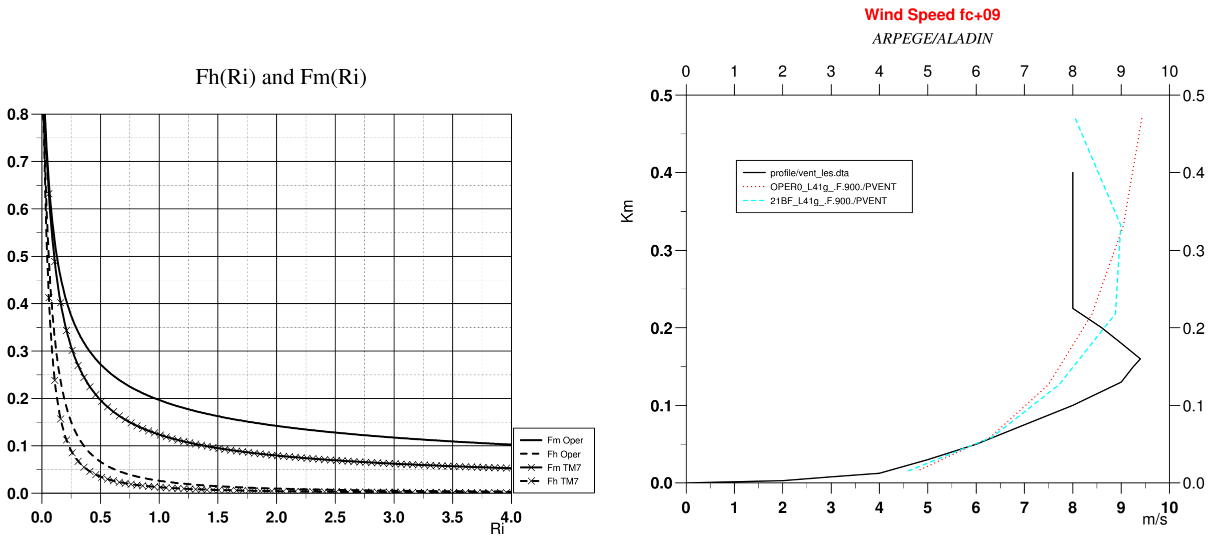

Figure 1: Left: Functions $F_{m/h}$. Full line=F_m, dashed lines=F_h and lines with stars are for $k = 5$. Right: Wind speed after 9h forecast with the 1D model on the GABLS case with the operational vertical level: Full line: LES mean profile. Dotted line: Operational version. Dashed line: modified scheme

The main results of the GABLS (Cuxart et al., 2004) are:

1. Operational schemes have a general tendancy to mix more than the research models with two important consequences:
   - the upper air inversion is not seen
   - the surface friction velocity is overestimated
2. Those using a Turbulence Kinetic Energy (TKE) scheme also oversestimate the mixing but to a smaller extent compared to the first order scheme.

In Météo-France, we have started to evaluate a TKE scheme based on Cuxart et al. (2000) in the 1D ARPEGE/ALADIN system. This scheme is used in the Méso-Nh model (research model). For the GABLS exercise, the first results with the TKE scheme are promising (fig: 3) and in agreement with the TKE results shown in Cuxart et al. (2005). Nevertheless, the surface heat flux and the friction velocity are underestimated compared to the LES data (Tab: 1) and the sensitivity to the diffusion coefficient require more experiment before to use in the 3D model.

3. THE 3D IMPACTS:

Following the GABLS results, the impacts of the modified "Louis scheme" should be limited to the cold region in stable condition but the interactive mixing length should also

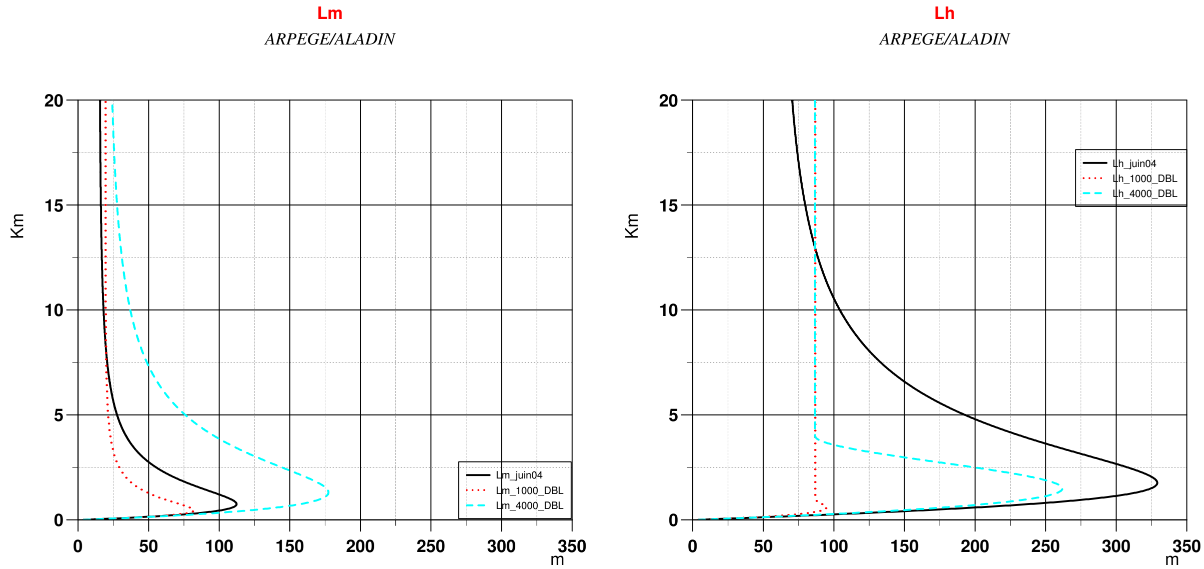

Figure 2: l_m, l_h, for two PBL height 1000m (dotted line) and 4000m (dashed line), operational mxing length: full line

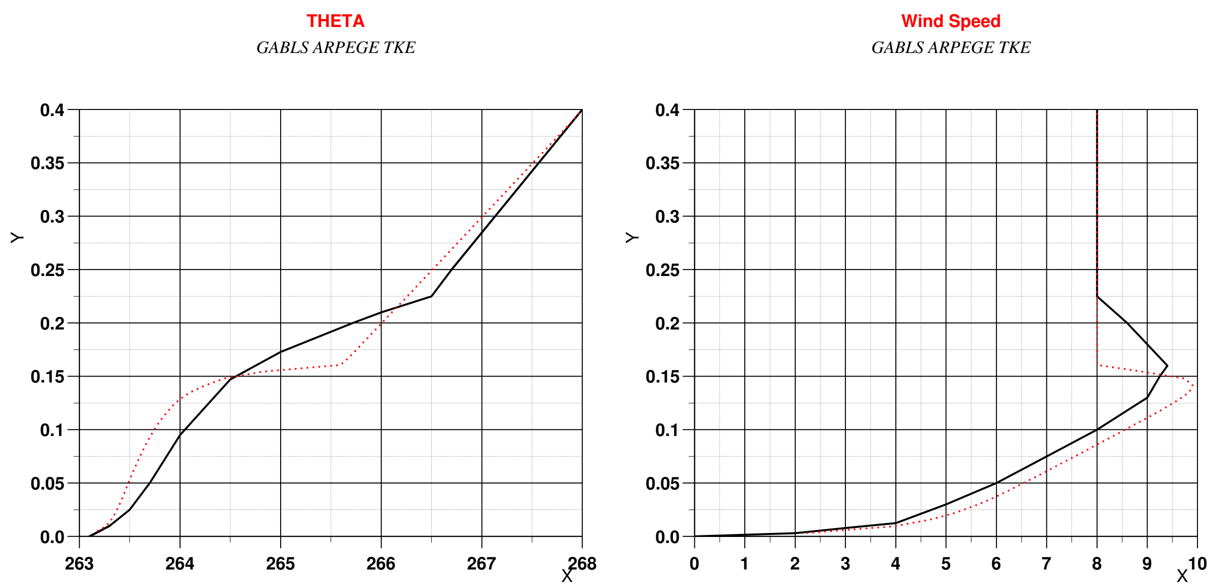

Figure 3: Potential temperature and wind speed on the GABLS experiment with the ARPEGE TKE scheme. Full line: LES mean profile. Dotted line: TKE scheme

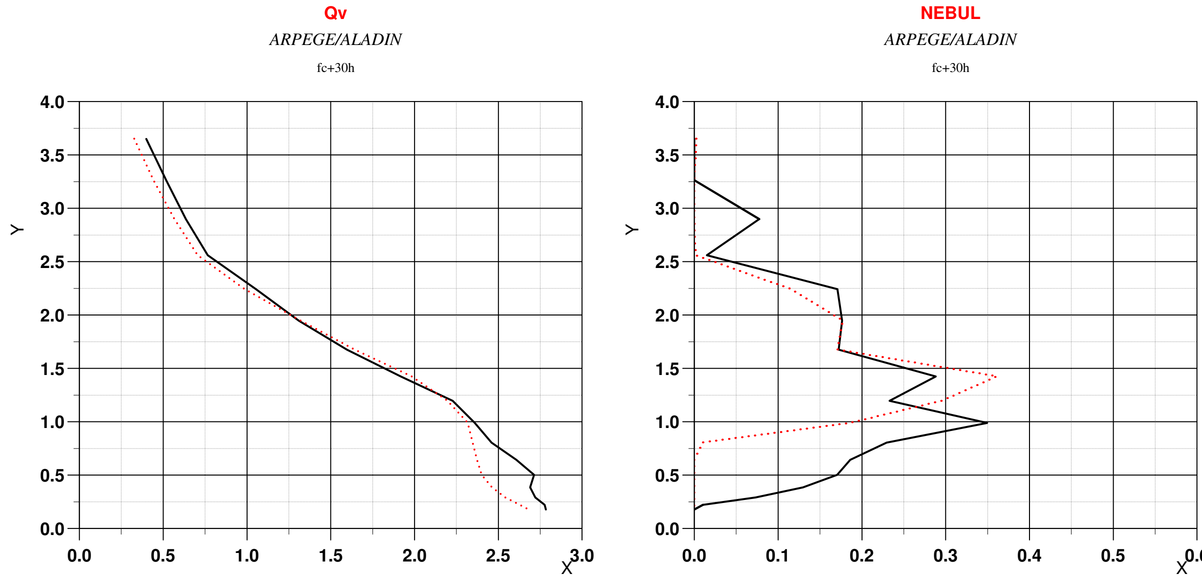

Figure 4: Mean of five 30h forecast at Roissy Airport (24/02/2004-28/02/2004). Left: vertical profile for the specific humidity. Right: vertical profile for the cloud cover. Dotted line: operational version. Fll line: modified ARPEGE

modified the treatment of the dry PBL, in particular over Sahara, where the PBL height can reached 4000m. The less mixing should improve the humidity profile with a moister PBL and consequently provides more lower clouds as shown in figure: 4.

Since the 16th December 2004, the modifications are tested in a parallel suite and should become operational in March. The scores are improved in the PBL over North America but also to a lower extend over North20 (Fig: 5). The wind direction is also improved specially over the EWGLAM domain (Fig: 6).

4. The Sodankylä comparison

Since spring 2004, the ARPEGE forecast is systematically compared to the Sodankylä data and the Hirlam RCR model. For the time being, no statiscal scores are computed but it is already very usefull to see in real time the RCR and ARPEGE forecast. During winter period and clear night with a strong net radiative cooling, the 2m-temperature error can reach 15°C (warmer) for the models, although the physics are very different (Fig: 7). Several reasons could explain this underprediction: clouds, vertical diffusion, surface and snow scheme. To search the main reason of this wrong forecast, the 1D model is very usefull, which is initialized with the 3D vertical profile and eventually corrected with the surface measurement. Thanks to the flux measurement and the deep soil temperature observation, the reason of the strong warm bias, in ARPEGE, has been diagnosed: in the ISBA scheme, due to the force restore approach, the soil heat transfer compensates almost the radiative cooling. A modification of the scheme to takes into account the insulating effect of the snow is under study.

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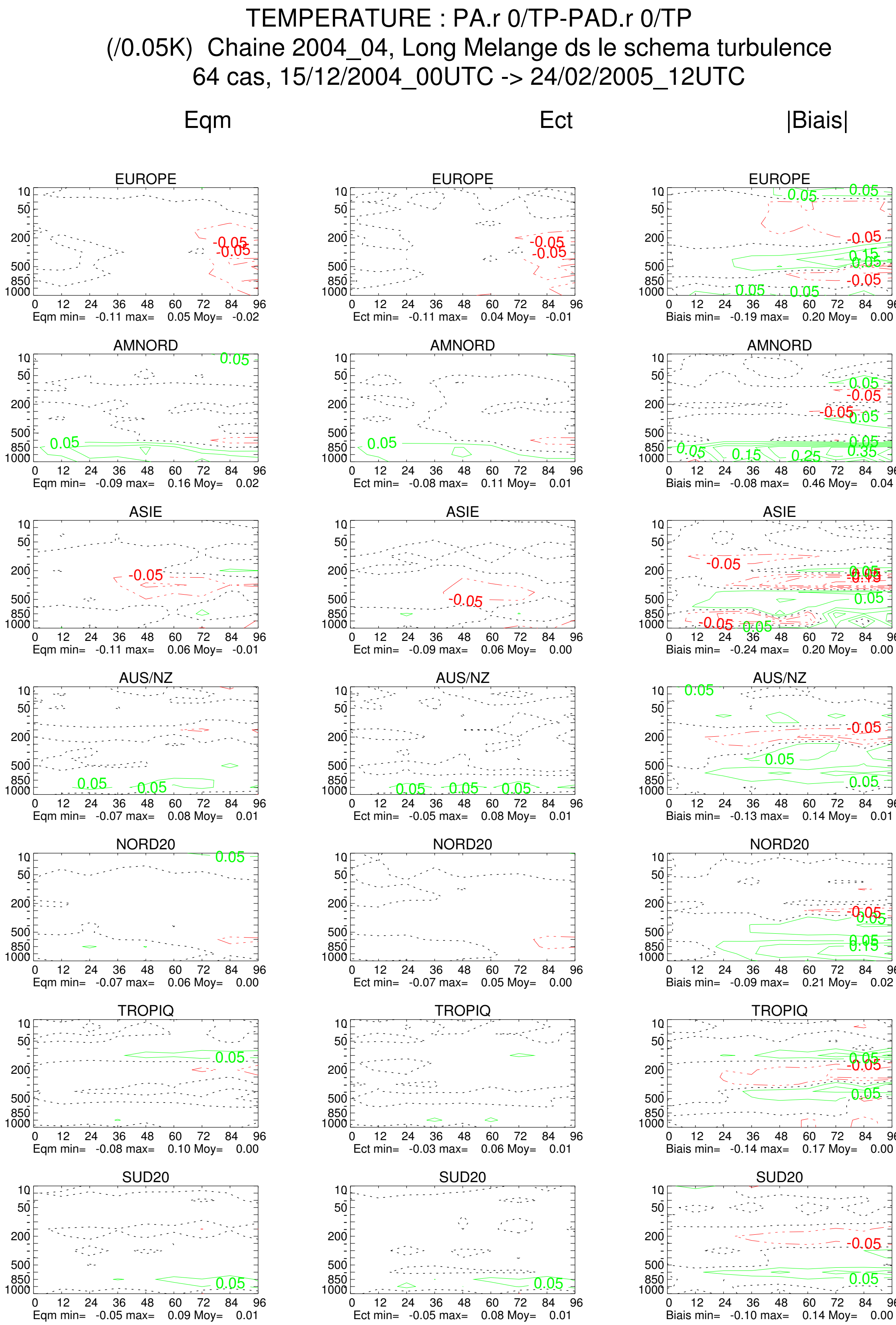

Figure 5: Score against the RS data for the temperature. Full line (or green) the test model is better

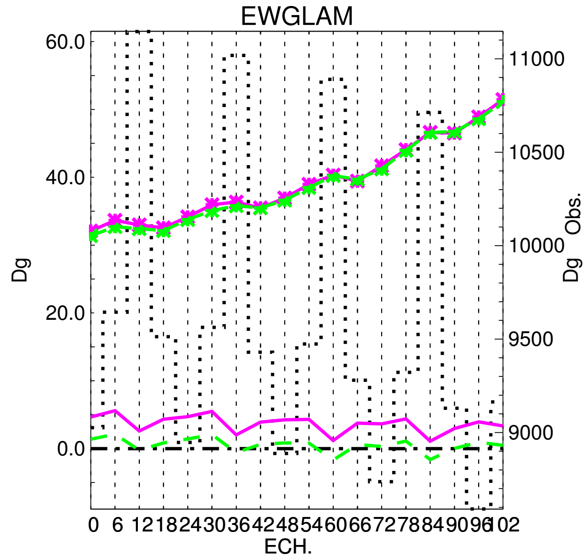

Figure 6: Score against SYNOP data for the wind direction (15/12/2004-24/02/2005). RMS and bias. Full line: oper. dashed line: test model

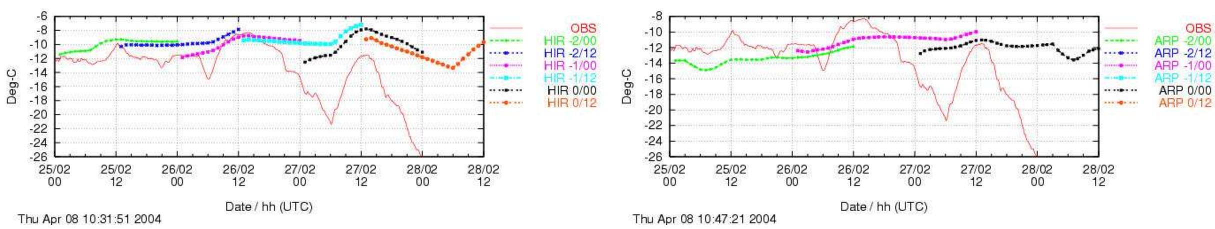

Figure 7: 2m Temperature at Sodankylä 25/02/2004 29/02/2005. Left: HIRLAM RCR model. Right: ARPEGE forecast

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