From the GABLS's result to the ARPEGE NWP system: an easy ride ?

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1. INTRODUCTION

The GABLS experiment described in (Holtslag, 2003) provides a clear intercomparaison for 1D model for the stratified boundary layer (SBL).

Following this intercomparison, the boundary layer parameterization (Louis et al., 1981), used in the numerical weather prediction (NWP) models ARPEGE-ALADIN, was modified in 2005 (Bazile et al., 2005).

However, the good behaviour of the turbulent kinetic energy (TKE) scheme on this case (Cuxart et al., 2006), with a wish to use the same PBL physical parameterizations in AROME, ALADIN, ARPEGE NWP and CLIMAT, the TKE scheme (Cuxart et al., 2000) and the shallow convection scheme (Bechtold et al., 2001) used in the non-hydrostatic model AROME have been evaluated in ARPEGE/ALADIN models.

In this contribution, I will describe how difficult it is to change the boundary layer parameterization in a NWP global model while keeping as a strong constraint the same tuning parameters for several 1D cases: GABLS1, EUROCS, BOMEX etc..

2. THE CONTEXT

The ARPEGE/ALADIN boundary layer is usually too dry, this is partly due to an excess of mixing. This weakness can be detrimental to the AROME coupling and, particularly, to the quality of low-level clouds or to fog prediction. It is generally well admitted for a better consitency between the coupling model and the coupled model to use the same physical parameterization specially for the boundary layer. Moreover, it was decided to use, unless for specific constraints, the same physical parametrization between ARPEGE-NWP and ARPEGE-CLIMAT.

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Sharing parameterization has many advantages such as multi scale validation (2.5km to 300km), numerical stability, several time step between 1mn to 30mn, many types of weather but which requires more time.

3. RESULTS

This excess of mixing, in particular for the operational model, has been clearly identified during the GABLS1 experiment (Cuxart et al., 2006). The low level jet does not exist in the old operational version (brown line, Fig:1). Two modifications have been done in April 2005 (Bazile et al., 2005): an interactive mixing length has been introduced, computed from a boundary layer height (Troen and Mahrt, 1986) and the stability functions $F_{m/h}$ have been retuned for stable cases. The wind profile is slightly improved with a maximum of the wind velocity around 300m, and several others parameters such as the friction velocity, the surface angle and the Monin-Obukhov length, but the wind profile is still far from the LES results. With the TKE scheme (Cuxart et al., 2000) and the BL89 (Bougeault and Lacarrère, 1989) mixing length, the low level jet is significantly improved (blue line Fig:1) .

In addition, this excess of mixing is partly responsible for the lack of low-level clouds in the Eastern apart of the tropical oceans (Fig:2). The cloud cover for low-level clouds is less than 0.1 instead of 0.6 in the ISCCP climatology (Fig:2). This under estimation is not due to a problem in the micro-physics scheme or in the formulae of the cloud cover. The Gewex Pacific Cross-section Intercomparison (GPCI) clearly shows that the boundary layer of ARPEGE is too dry for the operational version with a relative humidity of around 70% instead of 95%.

The new physical package contains: the TKE scheme with a top-entrainment parametrization (Grenier and Bretherton, 2001) , the AROME shallow convection (so-called KFB) scheme (Bechtold et al., 2001) and some modifications in the deep convection scheme. This package improves significantly the stratocumulus over oceans (Fig:3A)

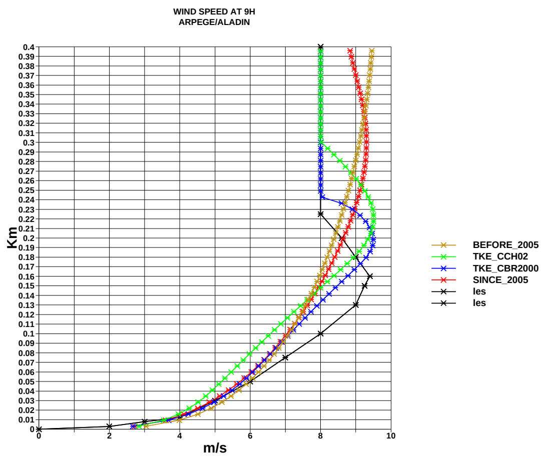


Figure 1: GABLS1: Wind profile after 9h forecast. LES=Black line. ARPEGE before 2005: brown line. ARPEGE after 2005: red line. ARPEGE with TKE: blue line. ARPEGE with TKE with Cheng et al. (2002): green line

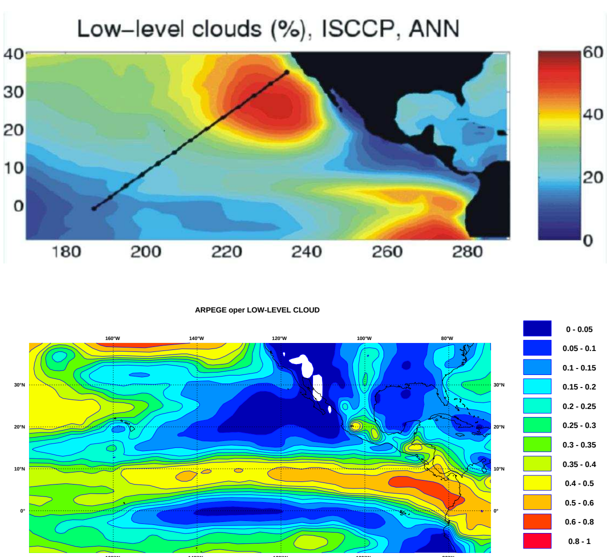


Figure 2: Top: low-level clouds from ISCCP Courtesy Cecile Hannay (NCAR) (JJA). Bottom : low-level clouds from ARPEGE (June 2007)

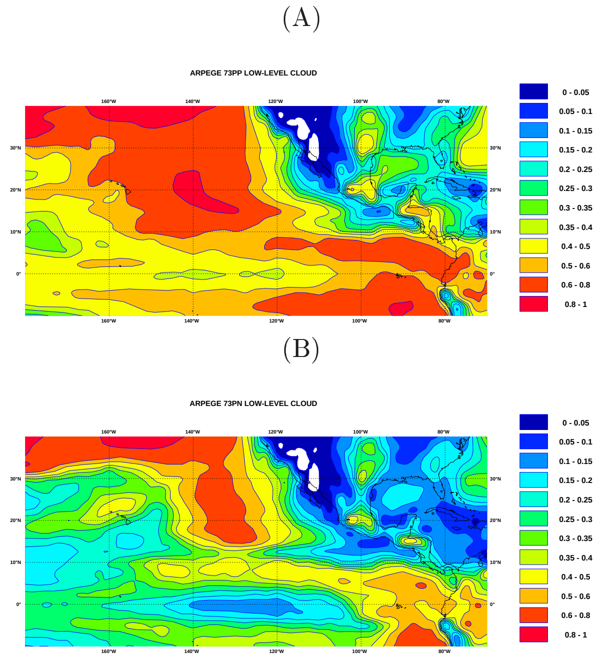


Figure 3: A: low-level clouds from ARPEGE with TKE+KFB (June 2007). B : low-level clouds from ARPEGE with TKE+KFB + thermal poduction from KFB + modified mixing length (June 2007)

and the temperature in the boundary layer. However, now the low cloud cover is over estimated by 20% and the wind in the boundary layer is increased and over estimated compared to the sounding data. Cheng et al. (2002) proposed new tuning parameters for the TKE scheme in order to increase the mixing of the wind. Those parameters improves the wind for ARPEGE and ALADIN, especially in winter, but the low level jet on the GABLS1 experiment is higher than the original version (green line Fig:1).

The root mean square (RMS) error on the temperature and the bais in the boundary layer against the sounding data or the ECMWF analysis are better over Europe and North 20° during summer (Fig:4) and winter.

Nevertheless, there is still a negative and appalling aspect to use operationally this package due to the increase of the RMS error for the wind in the tropics (Fig:5A). This deterioration is partly due to an increase of the over estimation of the Somalien jet at 850hPa (Fig:6). With the TKE scheme and the BL89 mixing length, there is a lack of mixing just above the inversion because the mixing length is very small with al-

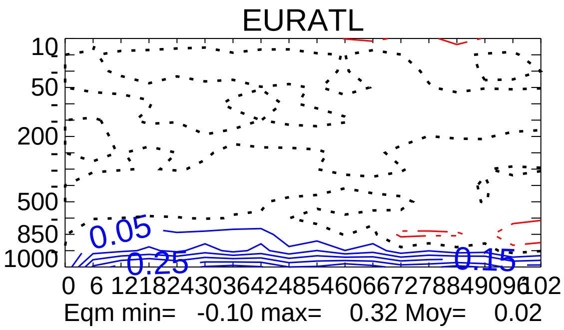
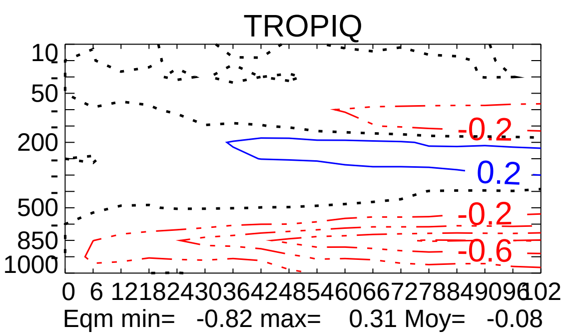


Figure 4: Difference of the RMS error for the temperature over Europe for June 2007 between the new physics and the operational. Blue: improvment.

(A)



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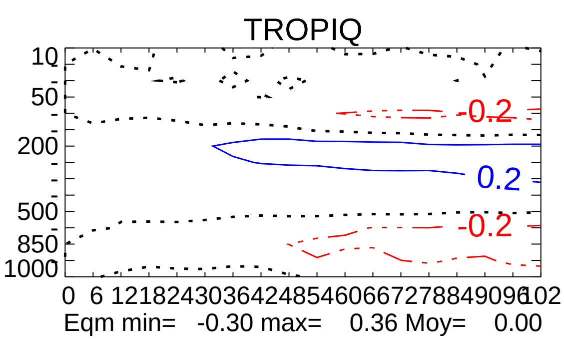

Figure 5: Difference of the RMS error for the wind in the tropics for June 2007 between the new physics and the operational. Blue: improvment. A: ARPEGE with TKE+KFB. B: ARPEGE with TKE+KFB + thermal production + modified mixing length

most no TKE, especially for cumulus. Lock and Mailhot (2006) have shown the impact of the enhancement of the turbulence length scales and the buoyancy production of TKE. Another option, already tested in Méso-NH, is to compute a thermal production term for the TKE equation from the KFB scheme. The BL89 mixing length has been modified in order to have in the cumulus cloud a maximum mixing length between the square root of the turbulent kinetic energy ($\tau\sqrt{E}$) (Texeira and Cheinet, 2004) and the original computation.

These modifications reduce significantly the RMS error of the wind over the tropics (Fig:5B) and the over estimation of the low-level clouds (Fig:3B)

3. CONCLUSIONS

From these encouraging results obtained from the GABLS1 experiment with the TKE scheme, the road to an operational use of the TKE scheme in the global model ARPEGE is very long, difficult, and requires several tunings and modifications to improve the performance of the operationnal model. However, now we can be really optimistic as there is a clear improvment in the ALADIN model and the last step but not the least, is to validate the new physical package in the 4DVar assimilation cycle for ARPEGE.

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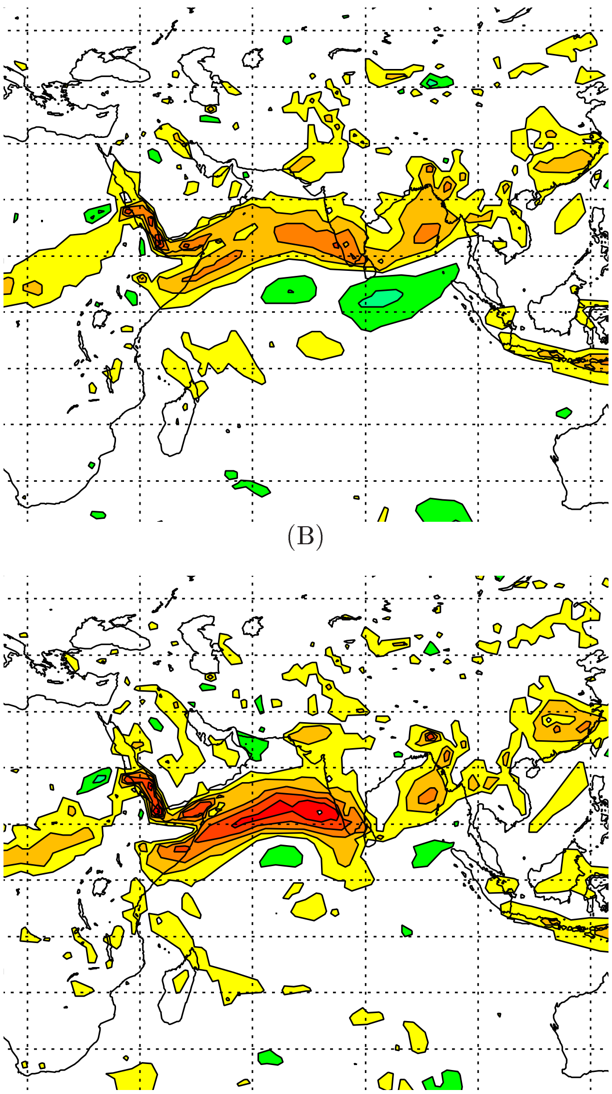
(A)



(B)

Figure 6: Mean bais against the ECMWF analysis for the 850hPa wind for fifteen 4-days forecast. A: Operational ARPEGE. B: ARPEGE with TKE+KFB

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