Improvement of the subgrid vertical mixing parameterization in operational hydrostatic models at Météo-France

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A global variable mesh model (ARPEGE), an hydrostatic limited area model (ALADIN) with a 9.5km resolution over several regions of the world and a non-hydrostatic 2.5km resolution model (AROME) over France are used operationally at Météo-France for weather forecasting. Important modifications of the subgrid vertical mixing parameterization used in the hydrostatic models became operationnal in February 2009. The Louis scheme (Louis, 1979) associated to a pseudo-shallow convection parameterization (Geleyn, 1987) has been replaced by a prognostic Turbulent Kinetic Energy scheme (TKE) associated to a mass flux shallow convection scheme. This development is characterised by a broad convergence between the parameterizations used in hydrostatic models with those of the operationnal non-hydrostatic model AROME.

The prognostic TKE scheme (Cuxart et al, 2000) is used with the tuning coefficients of AROME. The mixing length is computed using the formulation of Bougeault and Lacarrère (1989) (BL89) but with a modified combination between L_{up} and l_{down}. To improve the representation of stratocumulus, the scheme uses a top-Planetary Boundary Layer (PBL) entrainment parameterization following the ideas of Grenier and Bretherton (2001), with a modified integral formulation.

The shallow convection mass flux scheme is described in Bechtold et al. (2001). To avoid a double counting, the fluxes coming from the deep convection scheme are set to zero when the deep cloud has a height less than 3000m. Finally the condensation coming from the shallow convection scheme is an input of the micro-physics scheme, which means that the shallow convection scheme may indirectly generate precipitations. These two points have a very interesting impact on the quality of the precipitation forecast, mainly in summer (Figure 1).

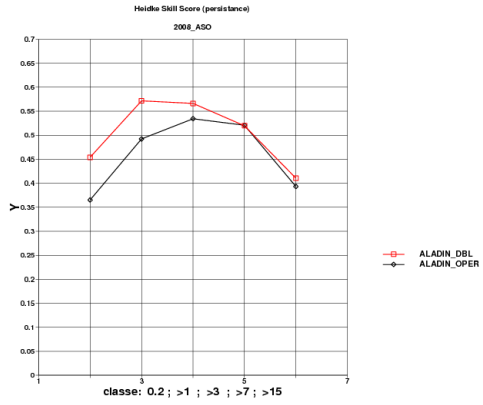

Figure 1 : Heidke Skill Score of the operational (red) and the old-operational (black) ALADIN France model during August, September and October 2008. All the precipitation classes are improved.

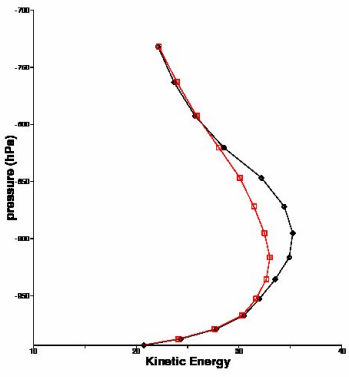

Figure 2 : Zonal mean over tropical area of the Kinetic energy (J/kg) with (red) and without (black) the connection of the turbulence scheme and mass flux shallow convection scheme. The benefical effect in the cloud layer is shown.

To solve a problem of too strong wind in the tropical PBL, it was decided to amend both the mixing length and the TKE, following the approach of Lock and Mailhot (2006). The main idea of the connection between the shallow convection scheme and the turbulence scheme is to suppose that in a PBL, where occurs shallow convection, the turbulent mixing is enhanced by the presence of clouds. First, a thermal production term of TKE coming from the shallow convection scheme is computed. Secondly, a local modification of the BL89 mixing

length is used. The BL89 mixing length is computed using the dry buoyancy and doesn't take into account the phase changes of water. In a cloud layer the result is an underestimation of the mixing length. The new approach consists of getting the thickness of the cloud from the shallow convection parameterization. When a shallow convection cloud is present L_{up} (respectively L_{down}) is now taken at least equal to the distance between the current level and the top (respectively the bottom) of the cloud.

By construction this modification has no impact when shallow convection is not active. The impact in the case of PBL with shallow convection cloud, mainly in the tropical area, is very important and leads to a large improvement of the global model ARPEGE (figure 2)

Changes outlined in this paper have a very important impact on the behaviour of the Météo-France hydrostatic models. The main result is a better thermodynamical representation of the PBL, with a large improvement of the low-cloud forecast (figure 3). The connection between the turbulence scheme and the shallow convection scheme is necessary, in ARPEGE, to avoid too strong wind in the tropical PBL. Limited area model ALADIN takes benefit of these modifications in the simulation of low-cloud and fog, but also in the quality of the precipitation fields..

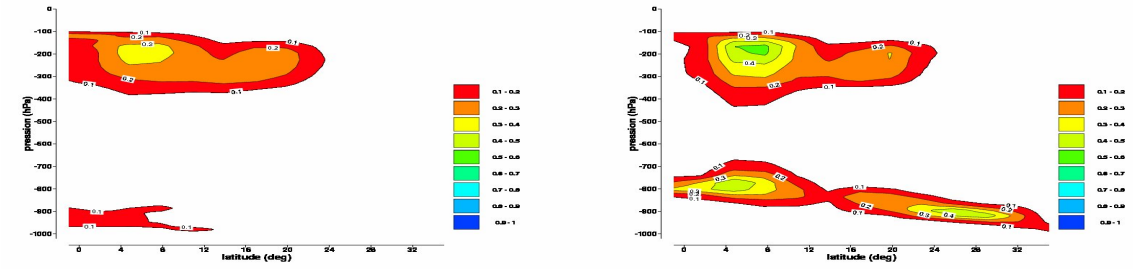

Figure 3 : Cloud cover of the old_operational ARPEGE model (left) for June 2007 along the GEWEX Pacific cross-section which starts from the Equator at 190° East to end by 35° North and 235° East close to Californian coast. Eastern stratocumulus are absent. Right : Same but with the operational model. Eastern Pacific statocumulus are now simulated.

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