Description of the so-called «shear-linked convection» parameterisation

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The idea of this additional parameterisation arose following some diagnostic studies done by André Simon on pathological potential vorticity (*PV*) structures near the surface in warm cyclogenesis situations of ARPEGE/ALADIN. It reminds the pioneering work of Thor-Erik Nordeng (Tellus, 1987, 39A, 354-375) attempting to parameterise *slantwise convection* in order to keep close to a zero amount of moist potential vorticity (*PVe*) and hence a bounded amount of *PV* in such situations (polar lows in his case). However Nordeng's work was based on Cartesian-LAM and high-latitude geostrophic considerations, all things difficult to sustain in the mixed ARPEGE/ALADIN framework. A solution was found, based on an idea that was unsuccessfully tried in EMERAUDE in 1989, in order to eliminate "*f*" from the same parameterized equations while getting rid at the same time of any horizontal derivative considerations in the calculation. The result will be nearly the same in case of a dominating geostrophic link, but the proposal below is more general and easier to implement. Pierre Bénard made however the remark that it was confusing to still call this a parameterisation of slantwise convection. Hence it was decided to keep the same initials to recall the link and giving a correct description was still possible when calling this a parameterisation of *shear-linked convection*.

Four hypotheses are needed to arrive to the form of one single equation that we shall then develop into an algorithm :

- like in all parameterisations of this kind, the effect will be taken into account in the convective routines by modifying the cloud ascent/descent properties (e.g. the undiluted ascent and descent shall go from neutral to slightly stable) within an unchanged environment; nature works quite differently since the *PV* instability might be removed by adiabatic sloping ascents encountering a modified environment, even if this is not a fully admitted description of the true behaviour;
- the mathematical exchange between horizontal and vertical derivatives is assumed to be done within the semi-geostrophic equations, but the real wind immediately replaces the geostrophic one inside it; this uses the space transformation from the verticals to the slanted "constant absolute momentum *M*" curves :

$$X_{sg} = X + V_g / f \qquad\qquad Y_{sg} = Y - U_g / f$$

- the link between the mass and wind derivatives is then taken from the thermal wind relationship under its potential temperature form :

$$f\frac{\partial u}{\partial z} = -g\,\frac{\partial(\ln\theta)}{\partial y} \qquad\qquad f\frac{\partial v}{\partial z} = +g\,\frac{\partial(\ln\theta)}{\partial x}$$

- once the above basic hypotheses have been applied to the dry case, one can jump to the moist case by simply replacing the squared dry Brunt-Vaisala frequency N^2 by its moist equivalent Nm^2, a step which should allow the elimination of unstable *PVe* patterns.

The central equation then reads :

$$\delta(Nm^2)=(\partial u/\partial z)^2+(\partial v/\partial z)^2 ,$$

which simply boils down to the fact that, in the balance between absolute vorticity and static stability as horizontal and vertical "resistance" to any motion, the non-vertical shear contributions to vorticity are, with respect to the reference situation of "vertical convection", displacing (hence the "δ" symbol) the neutrality target of the convective computation as expressed by the Brunt-Vaisala frequency, under its moist form.

The expression for the moist Brunt-Vaisalafrequency is taken from Equation (36) of the reference paper of Durran and Klemp (JAS, 1982, 39, 2152-2158) and slightly approximated plus rearranged in :

$$Nm^2 = \frac{g}{CpT}\cdot\frac{1+\frac{Lqs}{RT}}{1+\frac{L}{Cp}\frac{\partial qs}{\partial T}}\cdot\frac{\partial h}{\partial z}=A\cdot\frac{\partial h}{\partial z} \;\Rightarrow \delta(Nm^2)=A\cdot\delta(\frac{\partial h}{\partial z})$$

h being the moist static energy assumed to be conserved along the vertical saturated adiabatic in the reference neutral case and *A* being forced to monotonously decrease towards one when going higher up in the atmosphere (to avoid stratospheric oddities).

In order to modify as little as possible the computation of the saturated adiabatic profiles of the updraft and downdraft codes, the same trick is used to introduce the "δ" step as when doing the "ensembling entrainment" calculation: one replaces the geopotential thickness $\Delta\Phi$ of the layer (a quantity that already takes into account several effects) by a modified $\Delta\Phi$***** one, following:

$$\Delta\Phi^* = \Delta\Phi \;/ [1+\frac{g}{A}\left((\frac{\partial u}{\partial z})^2+(\frac{\partial v}{\partial z})^2\right)]$$

This is done three times, twice for the entraining pseudo-adiabats (updraft and downdraft) and once for the undiluted ascent of the updraft part (used as a reference in two other modulations of the entrainment rate).

According to preliminary tests, the impact of activating this parameterisation is important. It indeed removes part of the overestimation of warm cyclogenesis events by ARPEGE and/or ALADIN (Figure 1) and part of unrealistic intense precipitation patterns in ALADIN (see Figure 2 in the centre of France). It modifies the evolution of winter cyclogeneses (this will call for a retuning of the *Rid* part of the CYCORA-bis/ter settings). But it changes also the general circulation as well as the tropical water cycle so that it requires a retuning of some main parameters of the convection and/or PBL physics. One may wonder why ARPEGE and ALADIN now appear to need such a parameterisation while they are approaching horizontal resolutions that could allow an explicit removal of unstable *PVe* patterns by resolved motions. This is probably because the relative ratio of vertical to horizontal resolution decreased at the same time as horizontal resolution was increasing, since the end of the eighties. In any case this parameterisation is promising but will require a lot of studying.

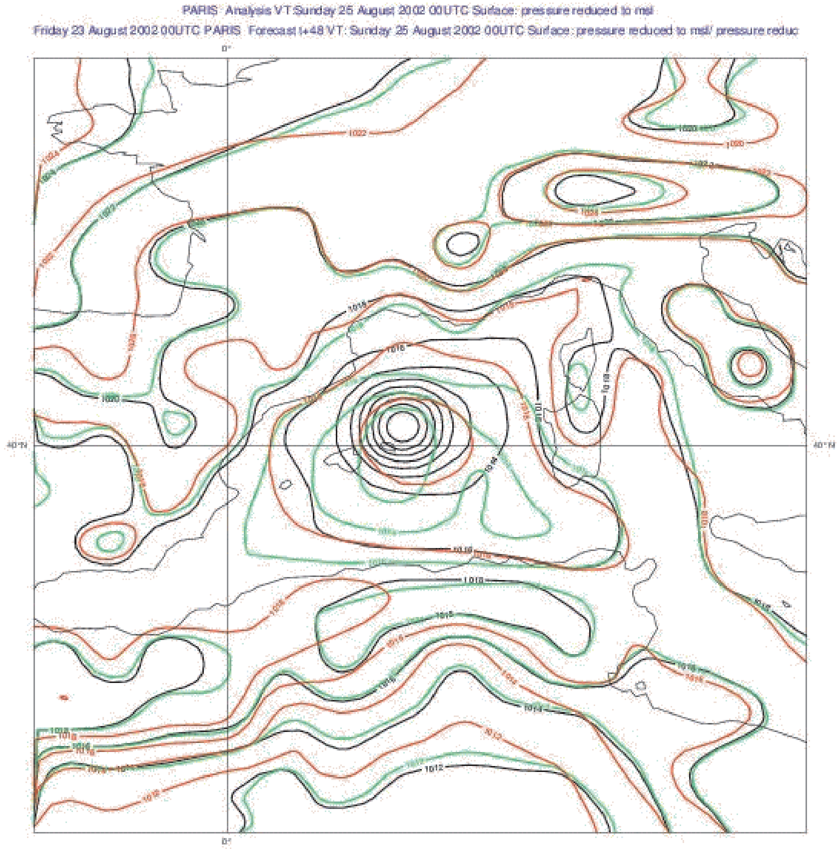

Figure 1: Sea level pressure valid for 2002082500. In red: analysis. In black: 48h ARPEGE forecast with the reference model. In green: 48h ARPEGE forecast when including the shear-linked convection parameterisation.

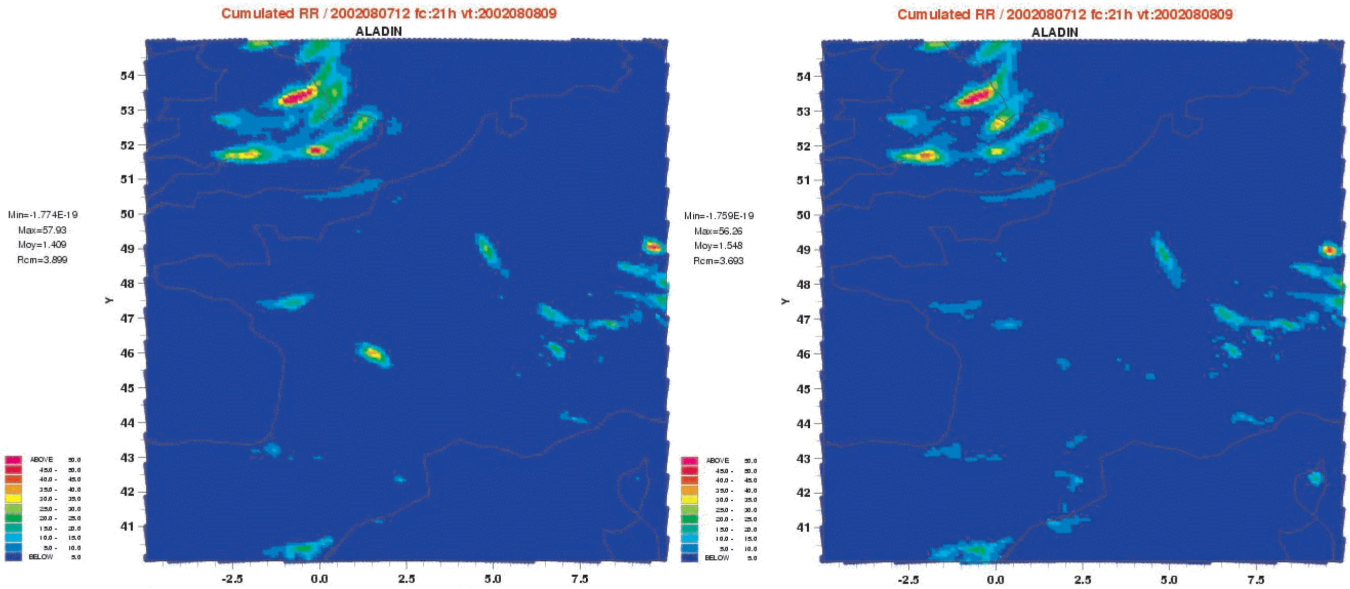

Figure 2: Cumulated total precipitation during 21h forecast with ALADIN-France model. The graphic on the right presnts the impact of the shear-linked convection parameterisation compared to the reference model on the left.