Further tests on the time smoothing of the shallow-convection parameterisation

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The preliminary work was performed by Martin Bellus on a suggestion of Eric Bazile following some diagnostic results of Martina Tudor (see ALADIN Newsletter 21). The proposed smoothing was afterwards cleanly introduced into the code and revalidated in order to prepare a possible operational implementation. Its main aim is to suppress a coupled time/space oscillation (the second aspect being mainly but not only in the vertical) created by the on/off character of the shallow -convection parameterisation (Geleyn, 1987, *JMS*, Special NWP Symposium Issue, 141-149).

The currently operational parameterisation works in the following way : whenever one may assume from local gradient-type diagnostics the likely presence of shallow convection, a quantity *"Zaux"* is added to "$\partial(C_p.T+F)/\partial z$" inside the computation of the Richardson number used for the stability dependency of the vertical exchange coefficients (not at the surface hence). This modification is not reported in the time-stabilising anti-fibrillation scheme because the spatial discontinuities are contradicting its basic hypotheses (see Bénard et al., 2000, *MWR*, **128**, 1937-1948). This explains the underlying need for the modification described below, even when all known problems of the anti-fibrillation scheme are cured. The formulation of *"Zaux"* is as follows, δ_{ci} being a Kronecker-type index linked to the pre-existence of moist convective instability as a necessary condition for shallow convection:

$$Zaux = \delta_{ci} .L.\ min(0\ ,\ \partial(q-q_{sat}\,[T,p])/\partial z)$$

When introducing the time smoothing procedure, one has to be careful with the use of the *"min"* function. While the correction to "$\partial(C_p.T+F)/\partial z$" should of course always be negative so that shallow convection systematically enhances vertical mixing via smaller Richardson numbers, the elimination of the intermittent behaviour requires the averaging of positive and negative "basic" quantities. Hence, using the "− & 0" time-step identifiers, the new scheme writes:

$$Zaux^* = \delta_{ci} .L.\ \partial(q-q_{sat}\,[T,p])/\partial z$$
$$Zaux^{*\,0} = min(0\ ,(Zaux^{*\,-}+Zaux^{*\,0})/2)$$

The new parameterisation (which requires a complex time-step to time-step transfer of the *"Zaux*"* information at all level interfaces) is activated under the switch LCVPPLIS and is currently only implemented for the two-time-level scheme (the correct averaging procedure would be different in the case of a leap-frog scheme, with three time-levels to consider and to combine).

Figure 1 shows the vertical and horizontal oscillations of specific humidity near the ground in the operational model (reference) and the corresponding modified run (with the temporal smoothing of shallow-convection parameterisation). The problem, essentially located in tropical and subtropical regions, is strongly reduced with the time smoothing.

Figure 2 presents the model tendencies, between day 4 and day 10 of a 10-day forecast, for temperature, specific humidity and kinetic energy, averaged on horizontal domains for the reference and modified models. The temporal smoothing of the shallow-convection activity enhances the vertical mixing, leading to a positive decrease of the humidification between 1000 and 600 hPa but a detrimental warming between 700 and 200 hPa. This non-negligible impact on global tendencies delayed its inclusion in pre-operational tests until it could be combined with some other fundamental change(s).

The ad-hoc character of the time-smoothing scheme indicates on the one hand that the shallow convection ought to be parameterized in a more modern way. On the other hand the regularising effect of the development described here gives more time to carefully design a replacement parameterisation (a mass-flux type scheme that will also try to build on the respective gradients of q and q_{sat} ?).

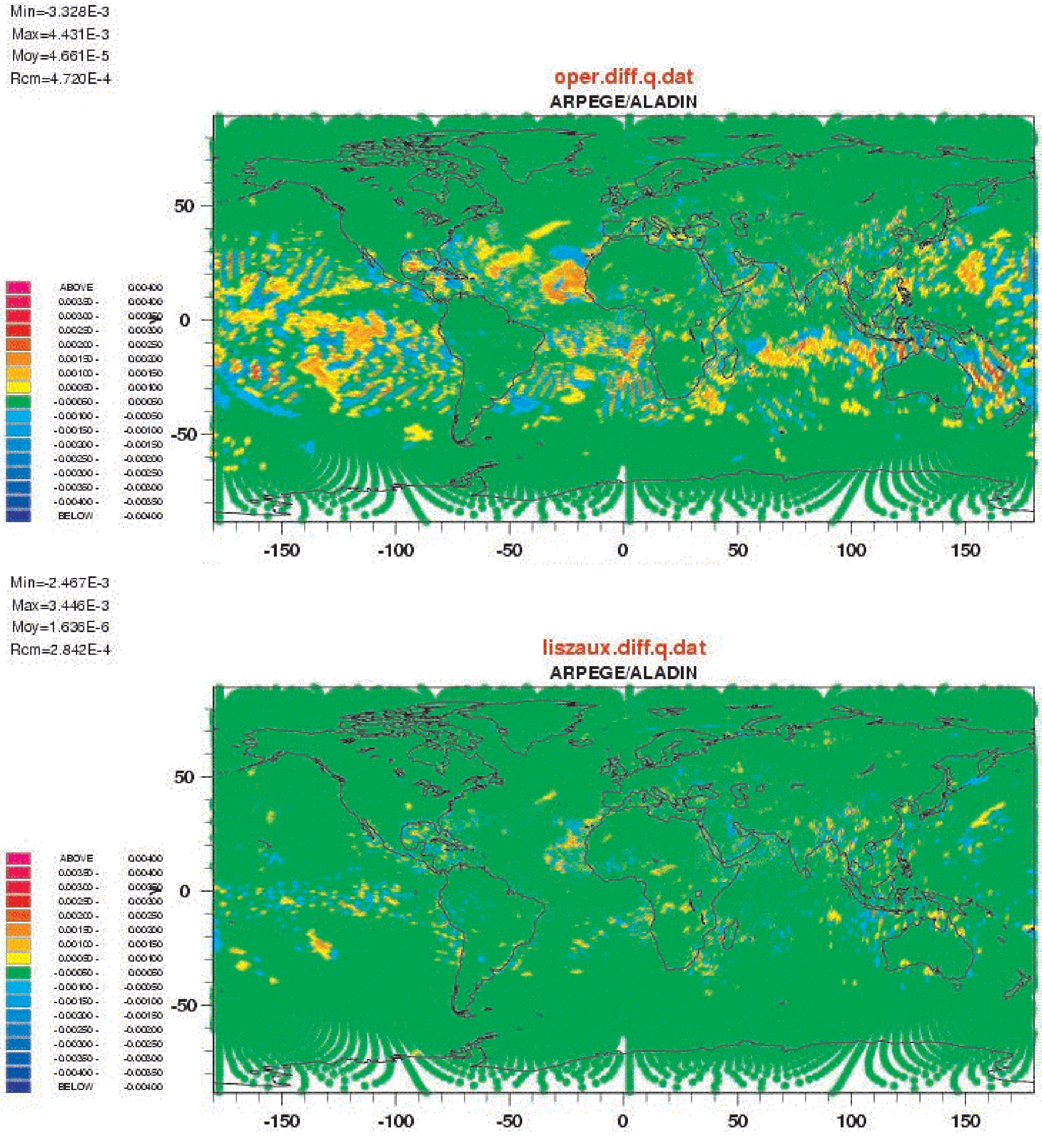

Figure 1: The quantity $(q_{41} - 2\, q_{40} + q_{39})$, q_i being the specific humidity at model level i, is plotted for the reference (top) and the modified (with smoothing) models after 24 h integration.

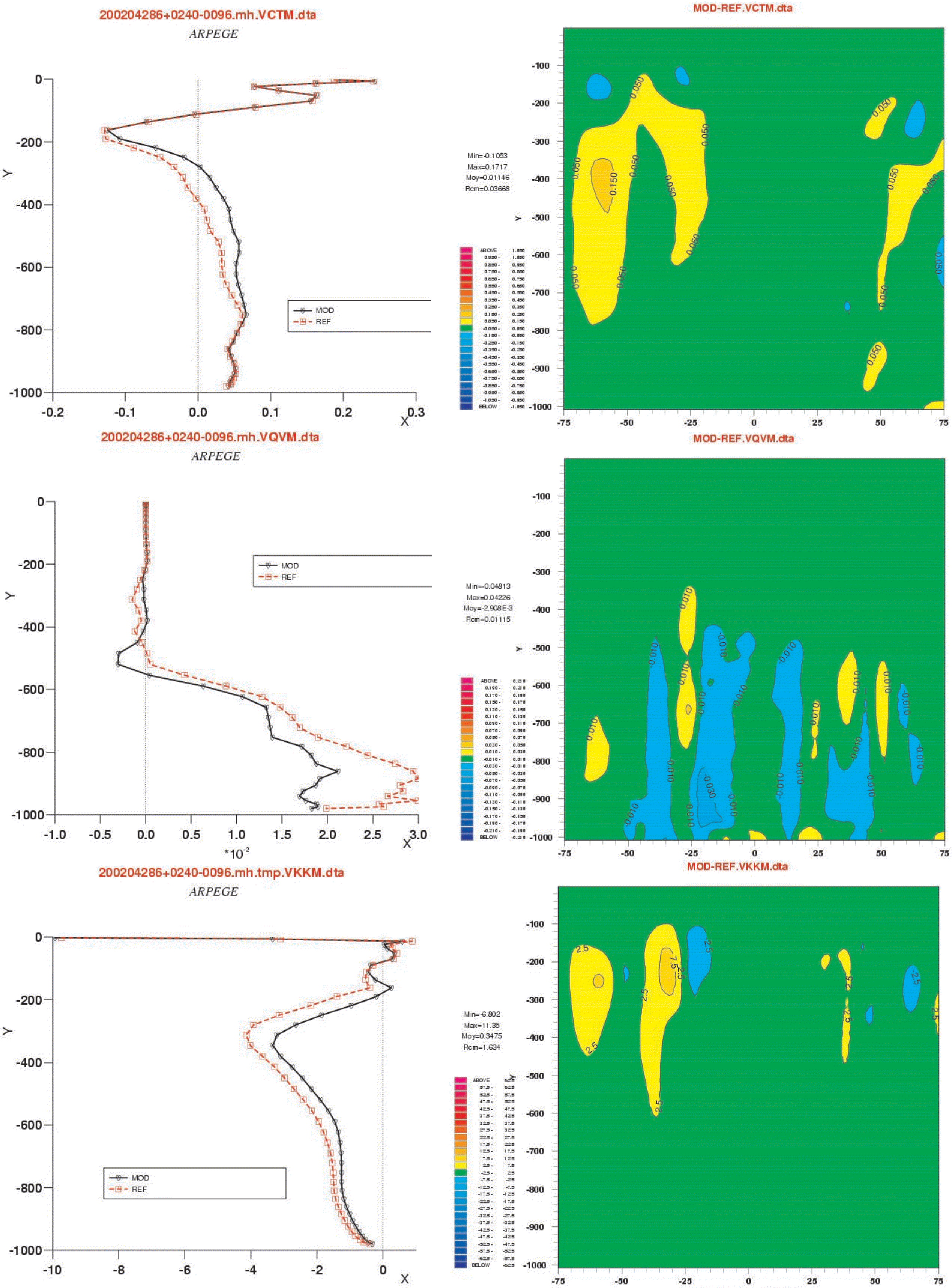

Figure 2: The model tendencies between day 4 and day 10 of a 10-day forecast, for temperature (top), specific humidity (middle) and kinetic energy (bottom), for the reference and modified models. The global tendencies for the two models are presented on the left. The differences of the zonal tendencies (modified model minus reference) are on the right.