A new "grid-point storm control" scheme in the ARPEGE NWP model

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1) Motivations - Introduction

It is explained in Bechtold (2008) that spurious grid-point storms can be generated in NWP models when convective heating/mixing (stabilisation) is not adequately represented (with too weak convection and/or turbulent schemes). The model can then become saturated under moist and/or strong forcing conditions, and an explicit turnover can develop to get rid of the instability.

(a)

(b)

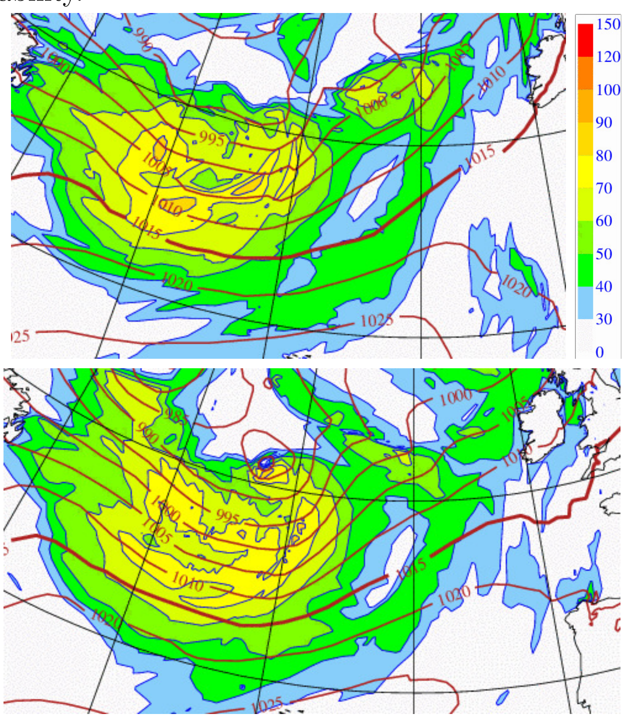

Figure 1: *Outputs of ARPEGE for the "low-resolution" operational version (T1198 / c = 2.2). The mean sea level pressure (MSLP, contours every 5 hPa) and 10 m wind speed (color scale, km/h) are plotted with the operational GPSC scheme for: (a) the analysis for the 11th of March 2017 (00 UTC) ; and (b) the 72 h forecast (from the 8th of March). The coasts from Ireland to Portugal are located on the right in (b).*

These unphysical strong ascents in the model are called "grid-point storm" (GPS). They can produce excessive large-scale rain, too deep lower tropospheric pressure systems and strong divergence at upper levels. They can destroy the actual Jet structure, and the model error can propagate and grow quickly, affecting heavily the forecast skill and the readability of the model synoptic charts.

An example of such a GPS is shown in Fig.1(b): there is a small region in the mid/north Atlantic where the isobaric lines are too close to each other (especially on the SW side of the low-pressure system) and generate too strong low-level winds (> 80 km/h). These patterns do not exist in the analysis chart in (a).

However, a curative scheme is active in the operational version of the French ARPEGE model. The current "grid-point storm control" scheme (GPSC) is implemented in the Bougeault convective scheme (1985), based on the convective equations of Yanai *et al.* (1973):

$$\left(\frac{\partial s}{\partial t}\right)_{\text{conv.}} = \omega^* \, \frac{\partial s}{\partial p} + K\,(s_c - s) - g\,\frac{\partial F_s}{\partial p}\,, \qquad (1)$$

$$\left(\frac{\partial q_v}{\partial t}\right)_{\text{conv.}} = \omega^* \, \frac{\partial q_v}{\partial p} + K\,(q_c - q_v) - g\,\frac{\partial F_q}{\partial p}\,. \qquad (2)$$

The turbulent fluxes F_s and F_q are removed from (1)-(2) for $s = c_p T + \phi$ and q_v so that the convection scheme might be aware of how the turbulence will modify the vertical profile (Bougeault, 1985). The mass flux ω^* is a measure of the net vertical ascent for the cloud profile values (s_c, q_c). The detrainment coefficient K is deduced from the conservation of moist static energy $\text{MSE} = s + L_v\, q_v$ along each vertical column.

Similarly to what is done with the removal of the turbulent fluxes F_s and F_q in (1)-(2), the GPSC scheme is based on a removal of the impact of the moisture convergence $\text{MCVG} = -\,\omega^* \partial q_v / \partial p$ for each levels and where the resolved vertical velocity is large ($|\omega| > \omega_0 \approx 1$ Pa/s). The impacts of the MCVG are thus added to the diffusion fluxes F_s and/or F_q. Moreover, the GPSC scheme is limited to moist regions where $\text{RH} = 100\ (q_v/q_{sat}) > 100$ %. It is expected that the knowledge of possible moist-saturated regions with high values of ω can enhance the action of the mass-flux scheme, with a possible removing of the observed spurious grid-point storms in ARPEGE.

A long trials and errors process showed (Bouyssel, 2012, in French) that an efficient method was to add the impact on the flux of static energy F_s only. However, some unexpected and unrealistic (dry-air) tropical waves were generated by this method. For this reason, the present version of the GPSC scheme only modifies the turbulent flux of specific humidity F_q.

2) Impacts of the higher resolution

An increase in resolution of ARPEGE is scheduled in 2019 by a factor 1798/1198 = 1.50 (thus by +50 %). Since the size of the finest resolved scales become 50 % smaller, the grid-point storm (GPS) must likely become more frequent and/or intense. A counting by eyes confirmed this risk over a period of 5 months: 18 GPS with the low resolution, versus 23 GPS for the high resolution.

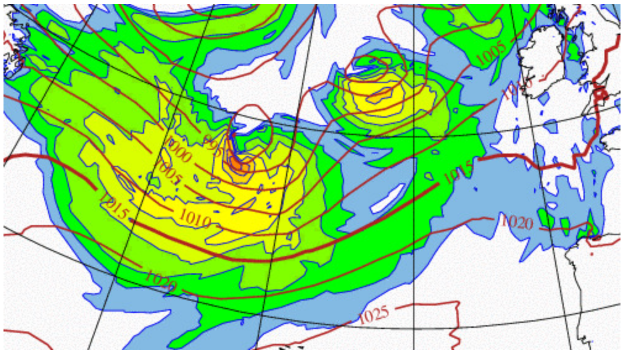

Figure 2: *The same 72 h forecast as in Fig.1(b), but for the new "high-resolution" in test (T1798 / $c = 2.2$).*

A typical example of such a new GPS generated by the high resolution is shown in Fig.2 (mid-Atlantic). A comparison with the Fig.1(b) shows that the GPS generates stronger low-level winds (> 100 km/h) than with the same GPSC scheme at low-resolution. Moreover the isobaric lines of MSLP are clearly asymmetric.

A test experiment made on the same day as in Fig.2 confirms that if the operational GPSC scheme is switch-off, then more GPS appear and generate frequent "bubbles" along the cold-front (see Fig.3).

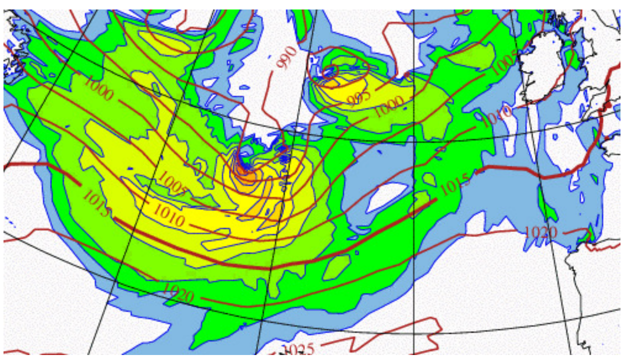

Figure 3: *The same as in Fig.2, but without any GPSC scheme. Two new GPS are observed, with enhanced winds, too.*

3) Impacts of the new scheme

The new GPSC scheme tested in 2018 corresponds to a removal of the impact of the moisture convergence MCVG via the turbulent fluxes of static energy F_s. Moreover, the threshold of 100 % for RH is now variable: it is imposed in the tropical region (in order to remove the spurious dry-air waves), whereas it is closer to 70 % for the extra-tropical cyclones (see Fig.4).

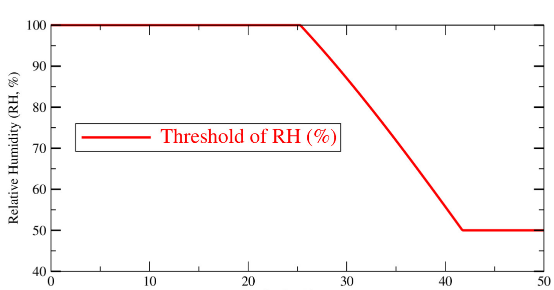

Figure 4: *The threshold of RH in terms of the latitude.*

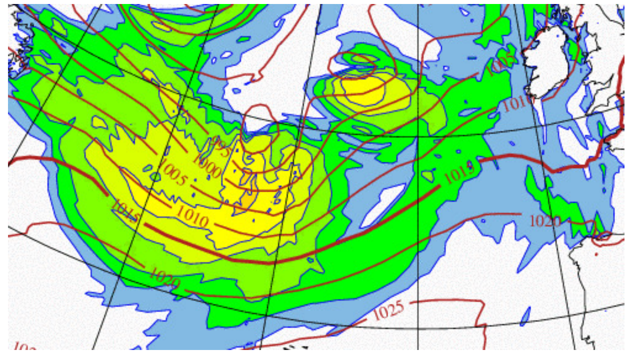

Figure 5: *The same "high-resolution" 72 h forecast as in Fig.2, but with the new GPSC scheme.*

The impact of this new scheme is shown in Fig.5. A comparison with Fig.2 shows that the grid-point storm is removed, with more realistic features for both the MSLP (more symmetric isobaric lines) and the 10 m wind speed (< 85 km/h). Moreover, the spurious tropical waves observed in 2012 are removed (not shown) by protecting the tropical region from the action of the new GPSC scheme via the threshold for RH. This new GPSC scheme is implemented in the test-suite in 2018 for a possible operational used in 2019.

4) Conclusions

It was necessary to improve the operational GPSC scheme for preparing the high resolution of ARPEGE (T1798 / $c = 2.2$). It seems that the new GPSC scheme leads to some improvements of some scores (to be confirmed, not shown).

However, the best solution to get rid of the spurious GPS in ARPEGE would be to improve the deep convection scheme itself. This has been confirmed by a test of the IFS scheme (Tiedtke 1989, Bechtold *et al.* 2014) in ARPEGE, with no more than 3 grid-point storms observed over the same period of 5 months (instead of 23).

References

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