Refinements in the parameterisation of radiative exchanges

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INTRODUCTION

This year developments started around the parameterisation of radiative exchanges in ARPEGE/ ALADIN. First the radiation scheme was modified in order to take into account the "Exchange With Surface" (EWS) term in the long-wave domain. The second issue was a modification of the ozone profile used by the model, introducing a geographical and temporal dependence. Third an important work was undertaken in Toulouse an Prague by Helga Toth, aiming at a more general improvement of the radiation scheme.

NEW TEST OF THE EWS PARAMETERISATION

The radiation scheme used in ARPEGE/ALADIN (subroutine ACRANEB) is far from expensive but on the other hand it relies on many approximations. This weak cost, compared with other schemes like *GRAALS,* used at DWD, or *FMR,* used in the Météo-France ARPEGE-climate model, makes it possible to call the radiation scheme at every time-step. This is very important in a fine-mesh model for well evaluating the interactions with clouds.

The parameterisation of the long-wave flux is based on the radiative transfer method. That consist of four main integrations : angular, vertical, spectral and optical. The optical integration is performed using the emissivity method. In this framework, the equation of radiative flux divergence can be formalised into three major terms. The first one is the cooling to space term (CTS), which is the part of the emission from a given layer transmitted directly to the space. The second term is the mutual exchanges between layers (EBL). The third term accounts for the exchanges between the layers and the surface (EWS). An exact solution requires the computation of $n(n+1)/2$ integrals (where n is the number of vertical levels). This is made in Roger Randriamampianina's "reference code", but this is very expensive. The particularity of the operational version of the long-wave radiation scheme in ARPEGE/ALADIN is that the two last terms are computed (and approximated) together.

For each layer two optical depths are computed, the first one is the optical depth between the layer and the space (δ_{CTS}), the second is the optical depth between the surface and the layer (δ_{EWS}). The minimum of these two optical depths is also computed (δ_{EXC}). Then, three terms are calculated :

- Fa : Exact calculation of cooling to space using δ_{CTS}
- Fb : Approximation of all the exchanges between layers (including CTS and EWS) using δ_{EXC}
- Fc : Approximation of the CTS term, using δ_{EXC}

The radiative flux is then computed in the following way : F = Fa + Fb - Fc

A new suite moved to operations on 11/02/03, including a new radiation scheme based on a exact calculation of the EWS term.

It is easy to see that the exact computation of the EWS term is possible using the δ_{EWS} optical depth. Two new terms are now computed.

- Fd : Exact computation of EWS term using δ_{EWS}
- Fe : Approximation of the EWS term using δ_{EXC}

The radiative flux includes two additional terms : F = Fa + Fb - Fc + Fd - Fe

A version of ACRANEB performing such a computation had been already prepared in 1996 by Neva Pristov (Pristov 1996), but unfortunately deemed as too expensive for its assumed "low impact". This version will be called *EWS* hereafter.

Within the framework of a more general test of the ARPEGE-climate physics (including the sophisticated *FMR* radiation scheme) in NWP conditions, it seemed interesting to test also the EWS version of ACRANEB. As expected, the impact is very important close to the surface. Figure 1 shows the evolution of an average of surface temperature over a Siberian area along a 96 h forecast in January 2002. Operational and *EWS* forecasts are presented, together with the corresponding operational analysis and first guess. The analysis is colder than the first guess, indicating that the model tends to introduce a hot bias. This is confirmed by the strong tendency of the operational forecast. Being colder, the *EWS* forecast seems to be better. Figure 2 presents the same diagnostics over a Saharan area. The tendencies are opposite and, this time, *EWS* code corrects completely the forecast error.

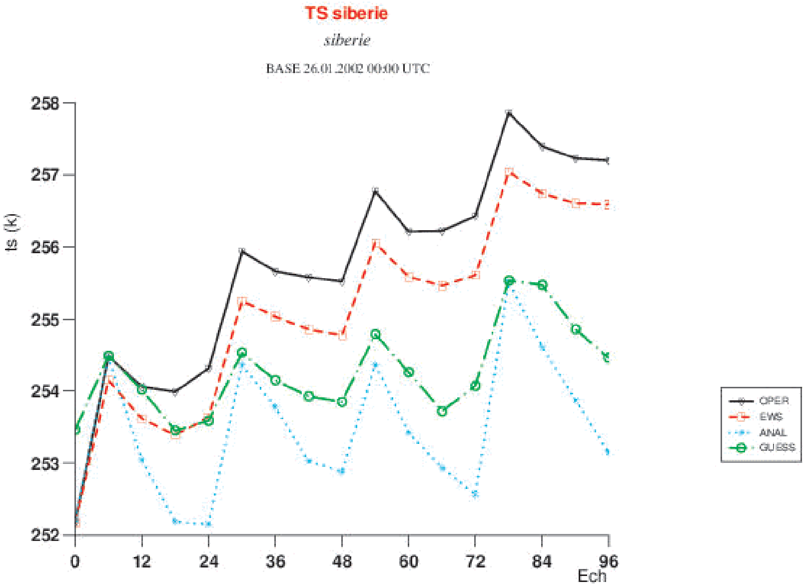

Figure 1 : Evolution along a 96 h forecast of an average of the surface temperature over a Siberian area during January 2002

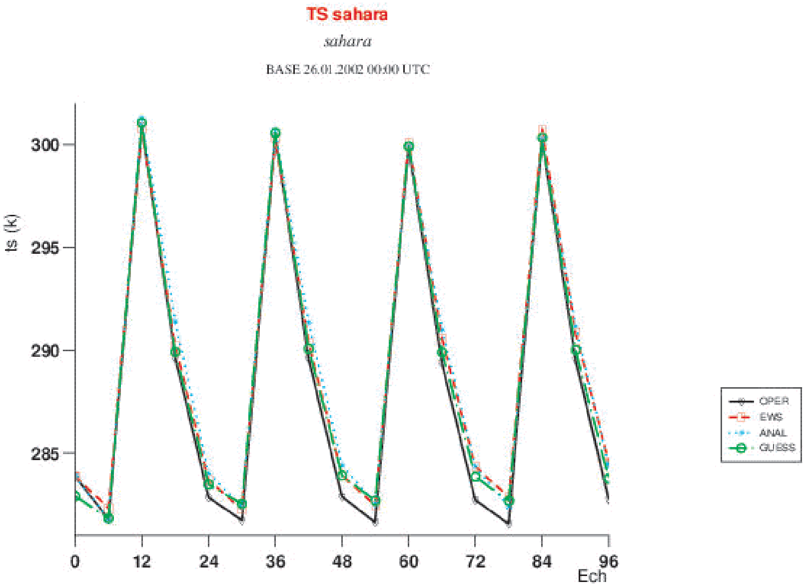

Figure 2 : Same as fig. 1, but for a Saharan area

The reason why the modification of the radiation scheme does not completely correct the problem over the Siberian area is linked to a too strong vertical turbulent transport in stable conditions. The new result of these experiments is that the modification of the radiation scheme has an impact not only close to the ground, but quickly (within 4d-var assimilation or during a medium-range forecast) on large-scale dynamics. Figures 3 to 5 show the corresponding modification of the Hadley circulation. Figure 3 presents the average over 14 days of the Hadley circulation in the analyses. On fig. 4 the average of the difference between the analyses and the operational 72 hours forecasts (valid at the same date) is plotted. Figure 5 is the equivalent of fig. 4 for the *EWS* forecast. One can see on fig. 4 a large difference between analysis and forecast at 300 hPa, close to 5 °N. This shows that the Hadley circulation is too weak. On fig. 5 the difference is smaller, consequently the Hadley circulation is better simulated in the EWS forecast.

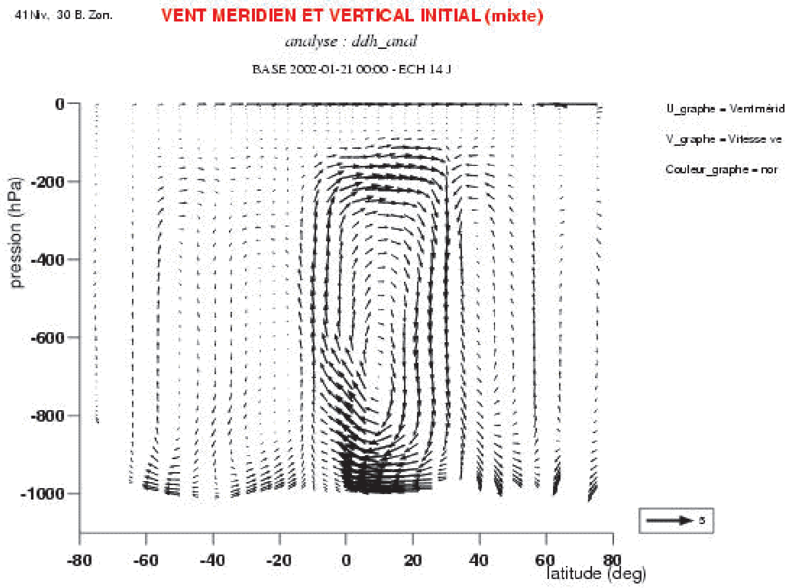

Figure 3 : Average over 14 days of the Hadley circulation, based on analyses

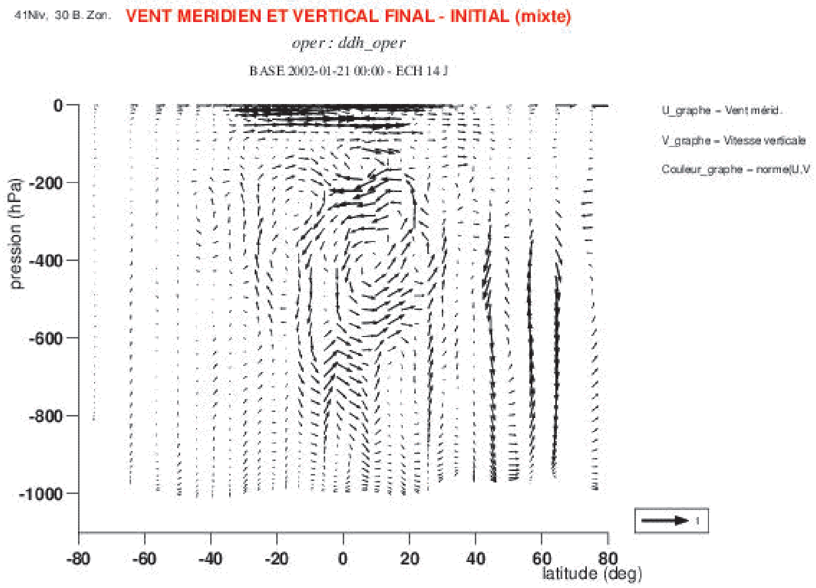

Figure 4 : Average of the difference between the analysis and the operational forecast

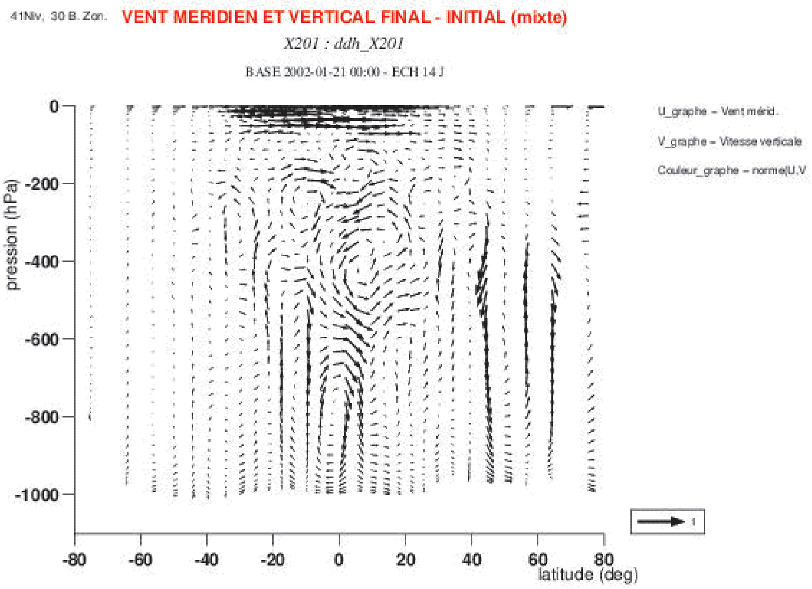

Figure 5 : Same as fig. 4 but for the EWS forecast.

Because of the improvement in the steady-state structure of the PBL brought by the changes in radiation code, it becomes possible to relax some of the modifications in the parameterisation of vertical turbulent transport in stable conditions, done for CYCORA (-bis, -ter) packages in order to have a good capacity of simulation for the storms of December 1998 and 1999. The new tuning, while keeping untouched this "storm" quality, involves a strong reduction of the overall friction in stable cases. This change leads to a far better thermal structure of the PBL in case of low-level inversions and to even less large-scale geopotential biases than with the sole EWS improvement.

All these differences have positive impacts on the large scale scores, as shown on fig. 6. This is the difference between the standard deviations of geopotential for the old, operational, suite and the new one. The reference is the ECMWF analysis.

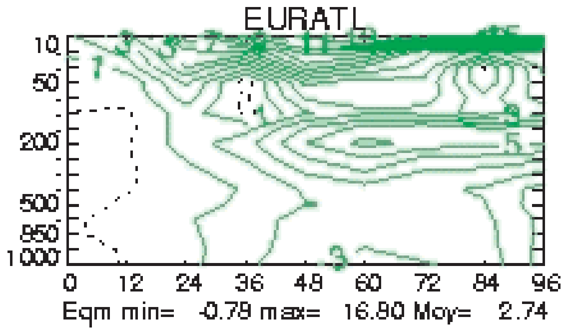

Figure 6 : Difference between the standard deviations of the geopotential of the old operational suite and the new one. The score is computed over an European area, the reference is the ECMWF analysis. Green corresponds to an improvement.

MODIFICATION OF THE OZONE PROFILES

Ozone profiles, in the operational ARPEGE-ALADIN physics are adjusted by an analytical function of three parameters. This profiles are currently the same at any point and any season. It was decided to improve this representation by preserving this function while making the parameters dependent on place and time. A similar experiment was performed by C. Rada, A. Sima and M. Caian (Rada et al. 2000). They used ozone profiles fitted to Bucharest measured data in the ALADIN model, integrated over the Romanian domain.

The UGAMP 3D ozone climatology was chosen as reference here. The UGAMP climatology was built up by Dingmin Li and Keith P. Shine, at the Department of Meteorology of the University of Reading. It is a 4-dimensional distribution of atmospheric ozone resulting from the combination of several observational data sets. For more details, see Li et al. (1995) or :

http://badc.nerc.ac.uk/data/ugamp-o3-climatology/ .

A specific program was written to adjust the parameters of the function to a given profile. It was observed that 3 parameters are not enough to take into account the variability of the profiles. As there are 3 degrees of freedom, 3 constraints to be respected (quantities to be preserved) were chosen. The first one is the ozone content integrated on the vertical, the second one the height of the maximum and the third one the value of this maximum. The ozone profile in the upper atmosphere are then not perfectly restituted.

A profile of ozone at the point (0 °E, 20 °N) in July is shown on fig. 7. The thin dashed line is the operational ozone profile, the thick dashed line the UGAMP profile and the red line the fitted profile. Another example is given on fig. 8 for the point (175 °E, 67.5 °S) in August. In this case one can see that the profile in the upper atmosphere is not good.

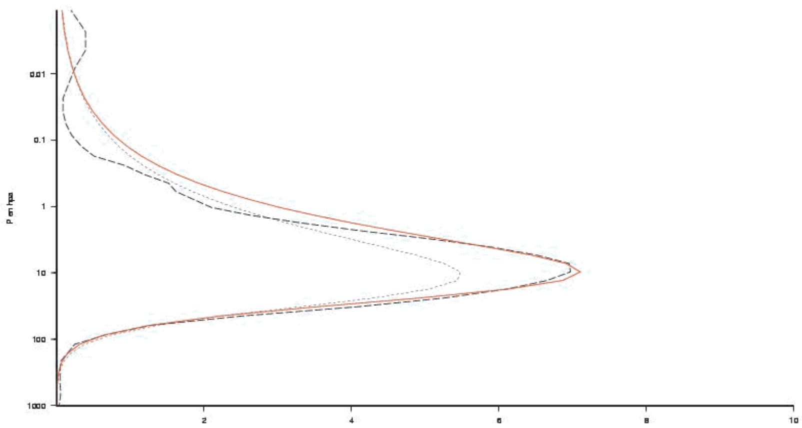

Figure 7 : Ozone profile in July at (0 °E, 20 °N), in Dobson Unit per hPa.
thin dashed line: operational profile, thick dashed line: UGAMP profile, red line: fitted profile

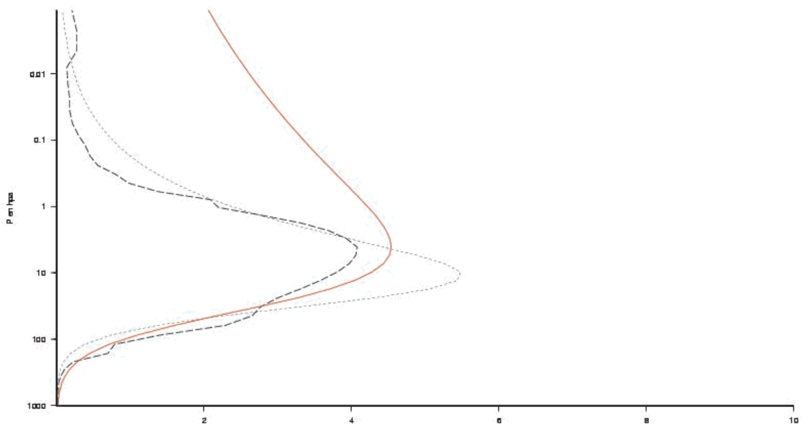

Figure 8 : Same as fig. 7 but for August at the point (175 °E, 67.5,°S).

A very important work was necessary to include the corresponding new fields in the data flow of the ARPEGE 4d-var, and also to automatically update them at the beginning of each month. A 4d-var experimental suite is presently running to evaluate the impact of this modification.

WORKS ON AN "INTERMEDIATE" RADIATION SCHEME

As said previously, the present radiation scheme contains a lot of approximations :

- The EBL term is approximated.
- There is no dependence on the type of cloudiness in the computation.
- There is only one spectral interval in the long-wave domain, with averaging of the absorption properties for each band using a Malkmus model and an integration over the interval using a Padé formula.

More complete schemes exist but their cost does not make it possible to call them at each time-step. It would be interesting to preserve this possibility and conceive a scheme of "intermediate" complexity. To advance in this way, exploration studies are necessary, to determine from which approximation the largest part of the error comes.

In this framework it seemed interesting to test if the deficiencies of the radiation code come from the single spectral interval or from other approximations. To do that a tuning of the coefficient of the Malkmus model was done by Helga Toth (2002). The problem is the choice of a reference. It is necessary to have a complete radiation code. *GRAALS* was chosen. To isolate the spectral integration approximation, it would have been necessary to use the "reference" code developed by Roger Randriamampianina in 2000. Unfortunately this code seems to have some problems in the 1D model. So the EWS code was used and it is not obvious that the approximation of the EBL term is negligible. As a preliminary conclusion this experiment shows that "a simple tuning cannot improve the deficiencies observed in the currently used scheme".

REFERENCES

Li, D. and K. P. Shine : A 4-Dimensional Ozone Climatology for UGAMP Models, *UGAMP Internal Report* **35**, April 1995.

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