7. André SIMON : "Study of the relationship between turbulent fluxes in deeply stable PBL situations and cyclogenetic activity"

Relationships between turbulent fluxes and cyclogenesis
(with aspect to the 20 December 1998' storm)

Description of achieved results during the ALATNET stay between 1.1.2002 and 31.5.2002

The need for this study appeared after several severe meteorological events, where the successful forecast of a cyclone was shown to be considerably dependent on a proper description of turbulent fluxes in the stable PBL layers.

One of the most significant cases was the rapidly developing cyclone in the northern Atlantic that hit France during 20 December 1998. Short and medium range forecast of this cyclone are strongly influenced by the critical Richardson number. The primary role of this variable is to bound the heat flux in situations with very stable PBL layers (when Richardson number is going to infinity).

In the current parameterisation scheme the tuning is provided by parameter USURID (see Geleyn, 2001). Generally speaking, small values of USURID (0.01 to 0.05) allow more heat exchange in the stable PBL and give the desired properties to forecast the cyclone. On the contrary, higher values (around 0.1) keep better inversion capabilities (Fig.1). Rather surprising is the fact that the current parameterisation "works" most sufficiently by Richardson numbers between 1 and 100 and not by extremely high values.

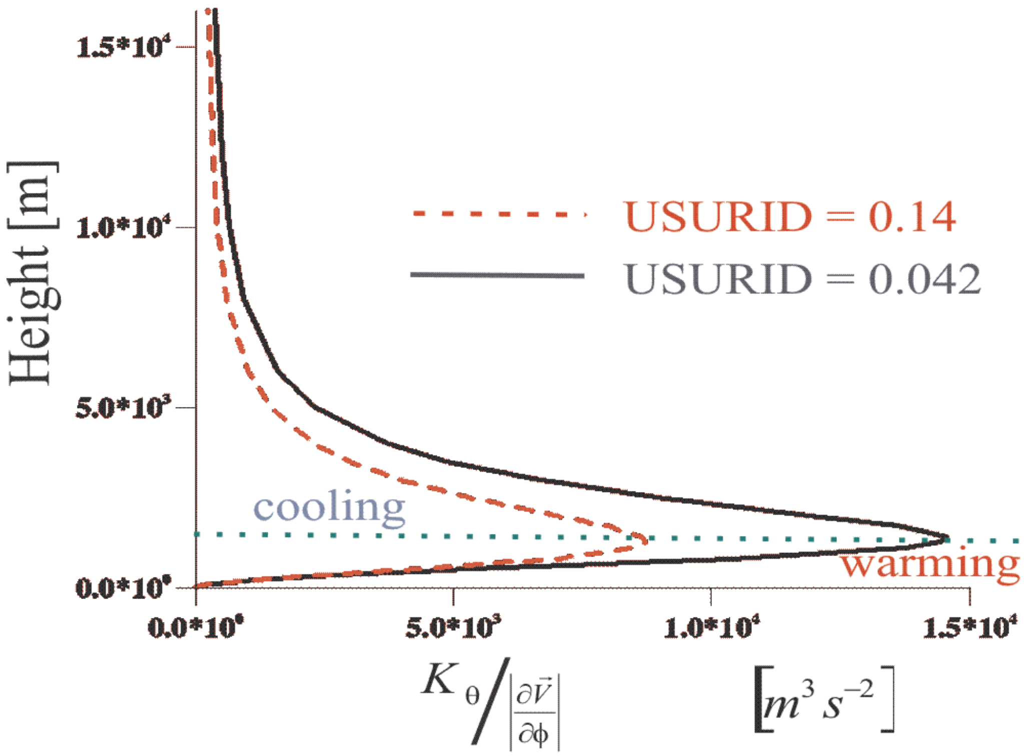


Fig.1 : Vertical profiles of exchange coefficient for heat by constant wind shear and by various values of parameter USURID. Profiles are computed for Richardson number Ri=4.5 . The green dotted line represents the height of "K" coefficient decrease. Below this level turbulent transport provides increase, above this level decrease, of potential temperature with time. The warming / cooling effect is more intense by smaller USURID value.

It was already shown by Bellus (2000), that the success of 84 hour forecasts of the cyclone depends on the Richardson number limitation along the first 21 hours of the run. This sensitivity was confirmed using the CYCORA-ter package in the beginning of 2002.

Because the forecasts of the mentioned cyclone using various setups of parameterisation are very close during this period, the transport of heat has not a direct influence on the process of rapid cyclogenesis (first 18 hours of computation - see Fig.2).

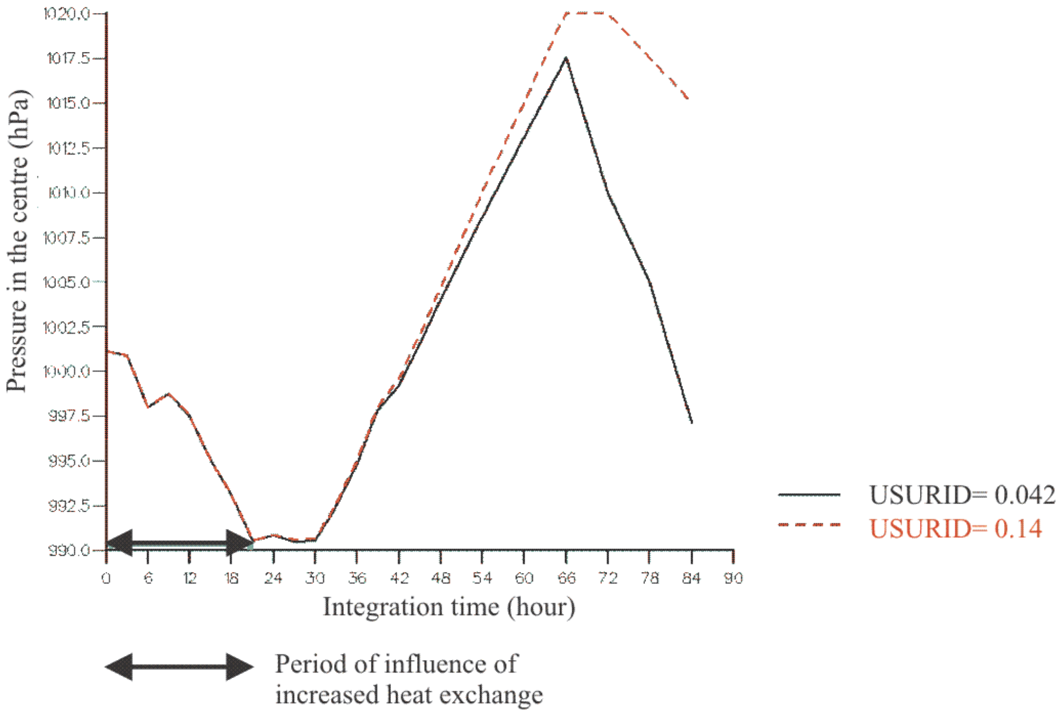


Fig.2 : Time evolution of mean sea level pressure in the centre of the "20.12.1998 storm". The 84 hour forecast of the ARPEGE model was based on 16.12.1998 00 UTC. Note the split of the two runs after 36 hours of integration and remarkable drop of pressure in the run with smaller USURID after 66 hours of integration.

Comparisons with the reference (operational) run show that a decrease of parameter USURID results in a decrease of static stability in the PBL in a few areas, mostly close to Newfoundland (Fig.3).

On the vertical cross-section through this area (Fig.4) one can see the effect of potential temperature increase in the lower PBL levels, with exchanges by cooling aloft and upstream.

The cyclone approaches the mentioned area after 36 hours of integration. In the same cross-section as in Fig.3 we can observe an increase in vertical velocities in the run with decreased static stability using a smaller USURID value, equal to 0.042 (Fig 5.). Consequently the forecasts of mean-sea-level pressure in the centre of the cyclone start to split when using different parameterisations of heat exchange. For smaller USURID (0.042) the decay of the cyclone between 36 and 66 hours of integration is slower and later the cyclone is rapidly reinforced, most probably due to presence of baroclinic instability (Fig.2).

Unfortunately, there is no possibility to forecast this (and any similar) event if the model forecast of surface pressure fails (that's the case for USURID equal to 0.14 or higher). Because the forecast error is mainly situated in low levels of the troposphere and in an area with lack of observational data, any other forecasting technique (e.g. use of potential vorticity inversion) would be most probably unsuccessful as well. Moreover already very high values of USURID (0.14) give significantly less static stability in the PBL when compared to the model analysis.

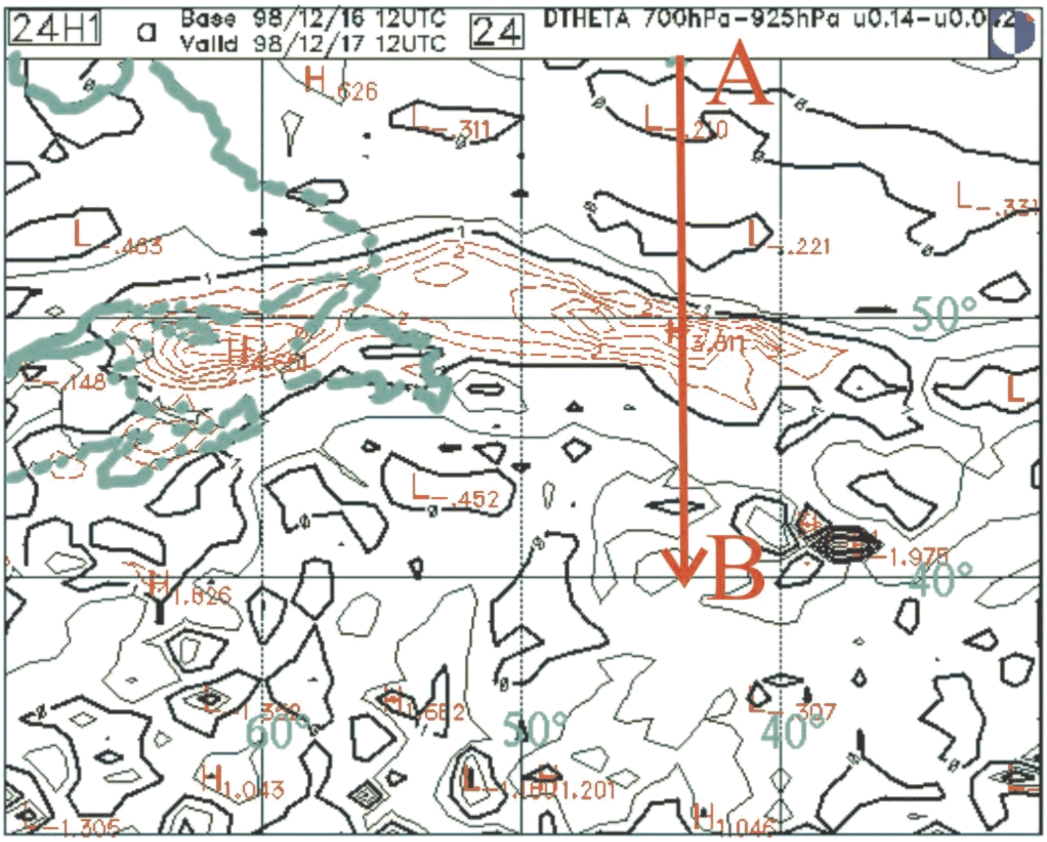


Fig.3 : Static stability changes due to enhanced turbulent transport after 24 hours of integration. The picture was obtained by computing differences of potential temperature between 925 and 700 hPa level and comparing the runs with USURID=0.14 and USURID=0.042. Areas with significant increase (decrease) in stability while going to higher (smaller) USURID are marked by dashed and red lines. The arrow draws the direction of the cross-section in Fig.4

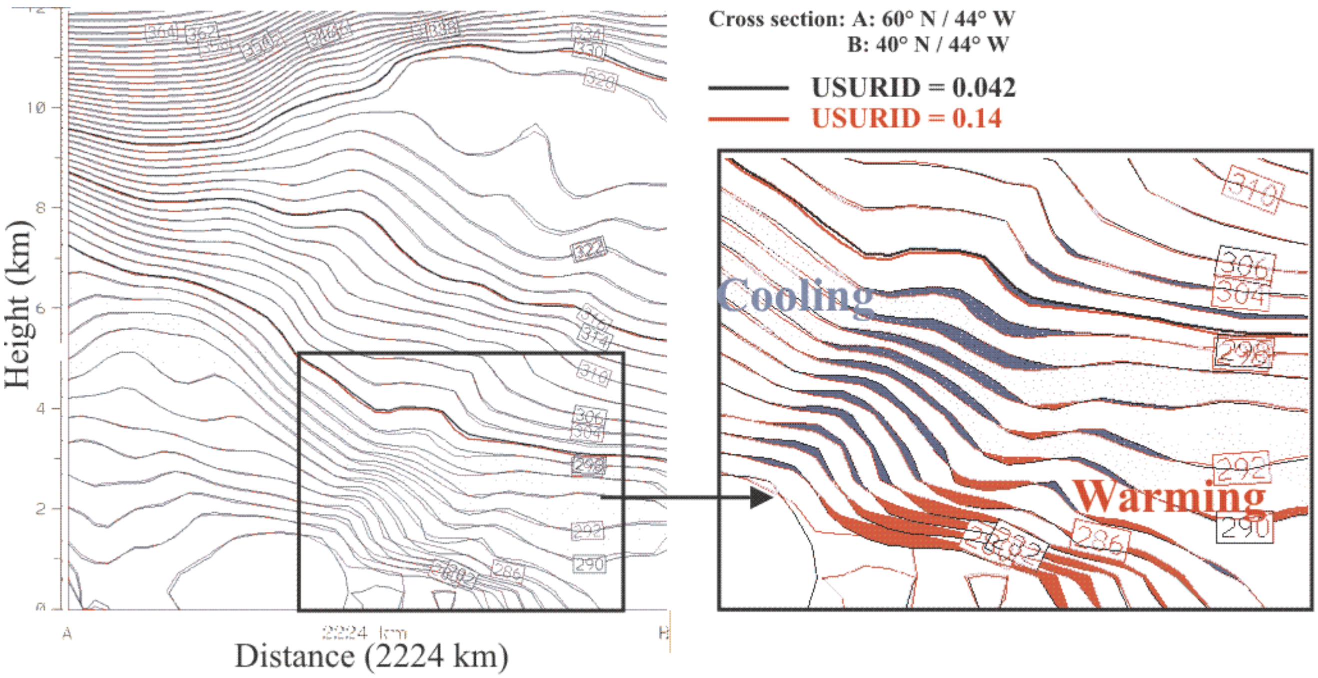
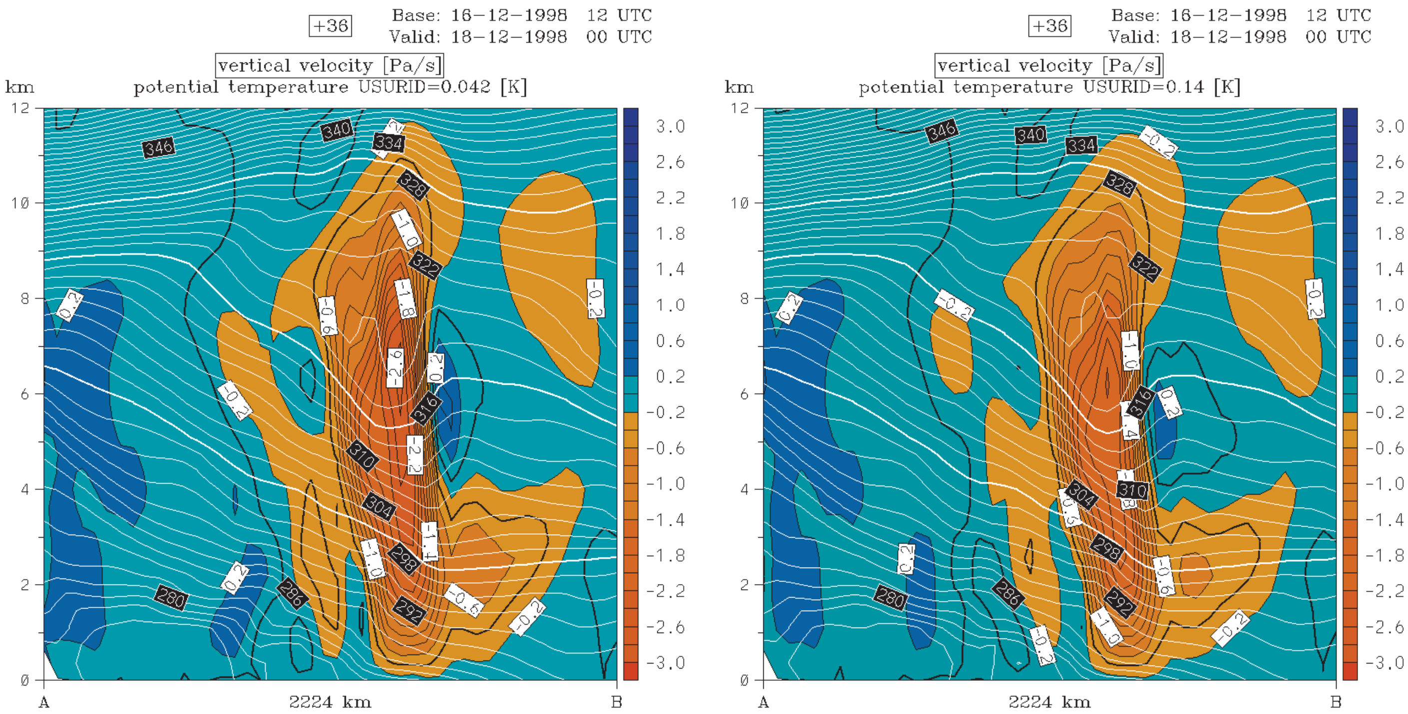


Fig.4 : Vertical cross section through potential temperature field computed from the same forecast as in Fig.3. Warming in low levels and cooling aloft is obtained by decreasing USURID, thus making the slope of potential temperature isolines steeper (decreasing static stability). In contrast to Fig.1, the warming / cooling effects result on a slope.



a b

Fig.5 : a/ Field of vertical velocity in the same vertical cross-section as in Fig.4 but after 36 hours of integration. Near the area of decreased static stability we can note more intense vertical motions in the mid-troposphere (run with USURID=0.042) comparing to run using USURID=0.14 (Fig.5b). After 36 hours of integration, forecasts of the cyclone using various USURID begin to split (see Fig.1).
b/ 36 hour forecast of vertical velocity in the run with USURID=0.14

Conclusion

One could deduce, that the physics - dynamics interface presented in this case is more or less accidental, nevertheless the parameterisation of turbulent transport played important role in several cases (among other the "famous" Christmas' storms in the year 1999). One reason can be, that the used diagnostic methods don't discover all particularities of the relationship between turbulence and cyclogenesis. Thus more objective techniques will be used for this purpose - i.e. sensitivity tests with adjoint model.

Adjustments of the current parameterisation scheme can lead at least to some kind of compromise in the cyclogenesis - inversion gap. It's possible to enhance the heat exchange over warm instable surface layers while keeping high USURID values over stable stratified lowest model layer. Such investigations already brought in the case of 20.12.1998 first promising results.

References

Bellus M., 2000 : Vertical turbulent transport parametrization (the profile for USURID parameter). Report on stay, Météo France

Geleyn, J.F., 2001 : A summary of the latest changes in the parametrization of turbulent fluxes and PBL processes. ALADIN Newsletter 20 / ALATNET Newsletter 3