Tests for new convection and large scale condensation in HIRLAM

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Abstract

The performance of Kain-Fritsch convection and Rasch-Kristjansson condensation (KF+RaK) in HIRLAM compared with the reference STRACO/Sundqvist scheme is analyzed using a typhoon case study and some parallel runs.

1 Introduction

The current HIRLAM moist physics uses a prognostic variable for cloud water content and diagnostic variables for cloud cover. The reference scheme is known as STRACO (Sass, 1997) which is a modified Sundqvist scheme (Sundqvist, 1989). Some of the features of STRACO are that it tries to ensure soft transitions between stratiform and convective regime, convection can be initiated at different levels and there is some attempt to take shallow convection into account. Also a parameter has been added to try to favor large scale condensation when increasing the model resolution. It could be said that STRACO has been built in a very empirical way to solve the known problems of the Sundqvist scheme. Nevertheless, the convective part is of Kuo type. This type of scheme has several limitations and most operational models have replaced it with a mass-flux convection. Unfortunately, although the large scale condensation and microphysics of STRACO/Sundqvist could be considered as state-of-the-art, its code, designed to be coupled with a Kuo scheme, makes it difficult to adapt it to a different convection.

The RaK condensation, developed for CCM3 climatic model (Rasch and Kristjansson, 1997) and adapted for HIRLAM by V. Ødegaard and C. Jones, takes many ideas from the Sundqvist parameterization but the modularity of its code makes it more suitable for further improvements. The Kain-Fritsch convective scheme (Kain and Fritsch, 1990) has been proved as a suitable parameterization for mesoscale simulations. It is a mass-flux scheme based on a buoyancy sorting approach (the entrainment/detrainment rates are adjusted depending on the environmental conditions). The original MM5 model code has been adapted to HIRLAM by C. Jones.

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2 A typhoon case study

Super-typhoon Flo was chosen for the third case of the mesoscale model intercomparison project COMPARE. The explosive intensification of this cyclone during a 72 hour period is a very suitable case for testing moist physics parameterizations. A short summary of COMPARE III and some sensitivity tests using the HIRLAM model can be found in Calvo (2000) and a comprehensive summary of this intercomparison exercise in Nagata et al. (2000). From the COMPARE results, no preferred moist physics schemes could be inferred. Using HIRLAM, the improvement replacing the reference STRACO scheme (or the original Sundqvist scheme) by KF+RaK is quite remarkable. Simulations at 50, 20 and 10 km resolution were carried out. Whereas STRACO was not able of reproducing the cyclone intensification, KF+RaK could simulate, at least qualitatively, the deepening (fig 1).

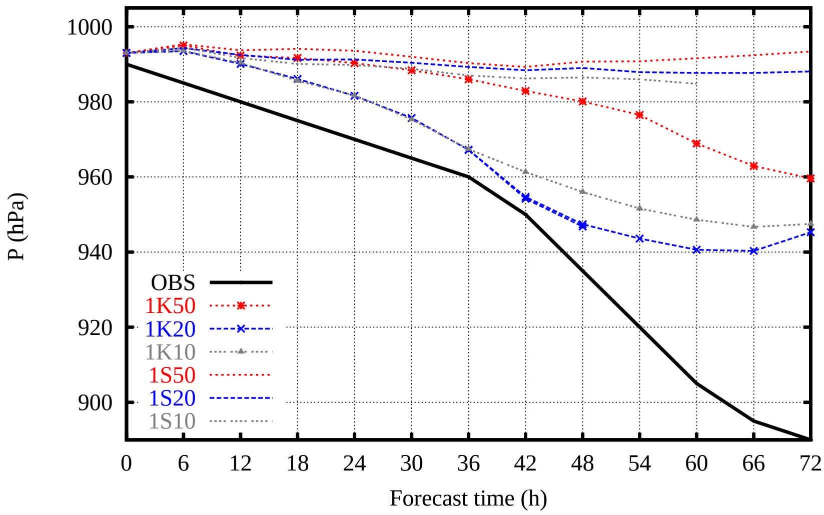

Figure 1: *Evolution of minimum sea level pressure of typhoon Flo. Comparison of HIRLAM simulations using two moist physics packages (see text) and three horizontal resolutions (50, 20 and 10 km) against observations. In contrast with KF+RaK (lines and dots), STRACO (3 upper lines) is not able to intensify the typhoon and showes small sensitivity to model horizontal resolution*

From the COMPARE results (Nagata et al., 2000) we know that the proper intensification is only achieved through a good simulation of the cyclone structure. Accordingly, the lack of deepening on the STRACO simulations can be explained by a very poor representation of the typhoon core. Besides, almost no improvement was found increasing the resolution. On the contrary, The KF+RaK simulations were able of reproducing the core structure, specially increasing the resolution from 50 to 20 km (fig 2). It remains to be understood why there is a lack of improvement in the KF+RaK simulation at the resolution of 10 km and why the deepening is stopped at the end of the integrations at 20 and 10 km. An interesting feature of the new scheme is the partition of precipitation into large scale and convective as a function of resolution (fig 3). An almost linear behavior is found for the increase of resolved precipitation and the decrease of convective part increasing the resolution. The total precipitation in the core area increases slightly increasing the resolution. With STRACO this partition shows almost no sensitivity to the resolution although the scheme tries to take this effect

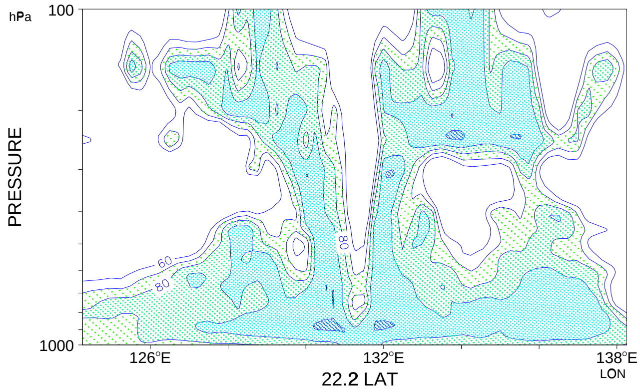

Figure 2: *Vertical cross-section of relative humidity through the typhoon core. The section corresponds to a H+60 integration at 20 km using KF+RaK. The model is able of reproducing the eye subsidence and the outflow around 200 hPa.*

into account explicitly.

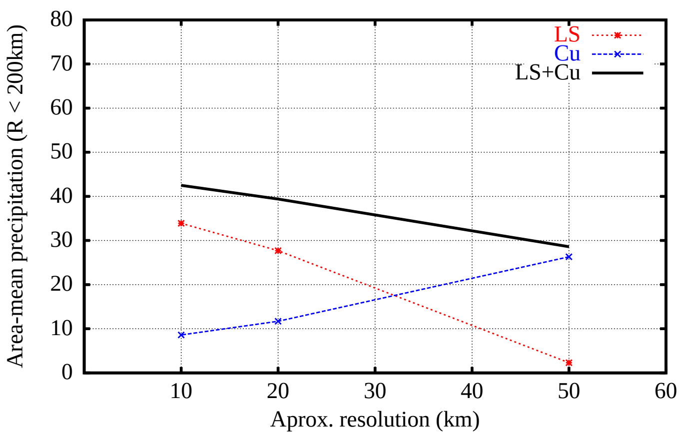

Figure 3: *Area-mean precipitation in the typhoon core (R<200km) as function of the resolution for the KF+RaK simulations. LS=Large Scale, Cu= Convective and LS+Cu=total*

3 Parallel runs

Two periods, defined by the HIRLAM management as reference periods for code testing, were selected to compare STRACO with KF+RaK: February 17-28, 2000 and May 6-20, 2000. During the spring period a lot of convective activity took place. The DMR area with operational strategy, boundary files and analysis was used for the simulations at 50 km and a nested experiment, also using the operational 50 km resolution analysis, was built at 20 km (fig 4). All the integrations were carried out at ECMWF's Fujitsu computer, starting from 12 UTC and with a length of 48 hours.

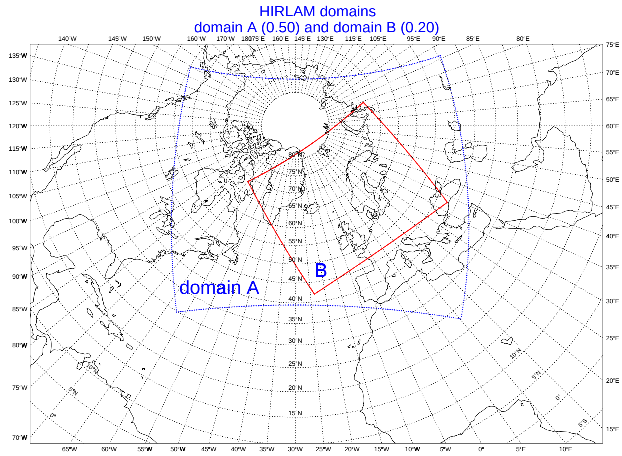

Figure 4: *Integration areas at 50 km (domain A) and 20 km (domain B) resolution for the parallel runs (see text)*

Objective verification against observations showed almost no impact on the mean sea level pressure (fig 5). Indeed, a slight degradation could be seen at 50 km using KF+RaK. For cloud cover, a reduction of the root mean square error (RMS) was found with the new schemes and a slight improvement of two meter temperature in agreement with the improvement of cloud cover. In contrast with the overestimation of clouds with STRACO, KF+RaK showed an underestimation (fig 5)

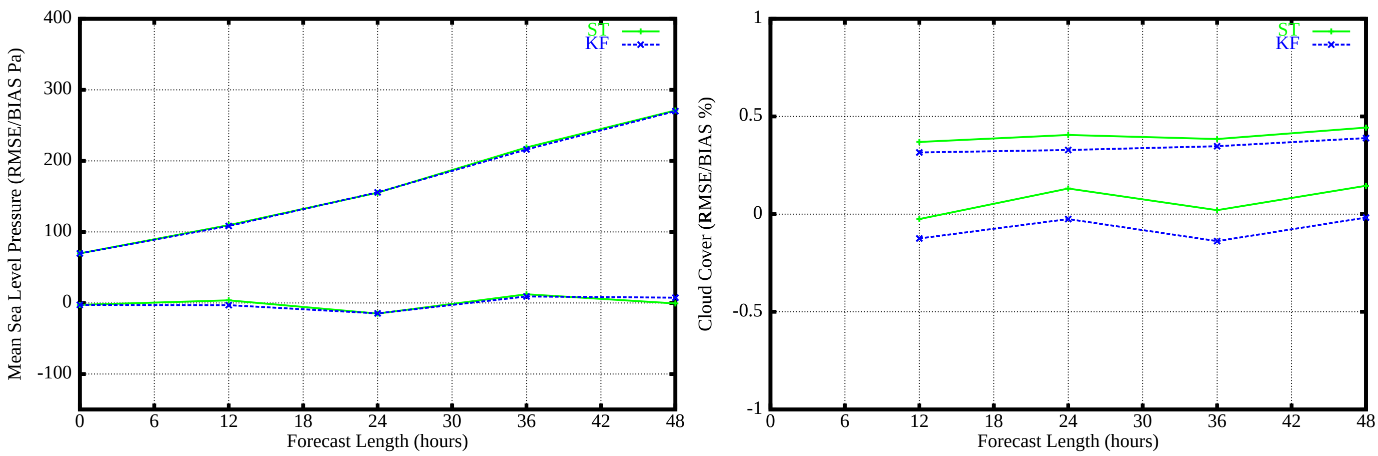

Figure 5: *Objective verification against EWGLAM stations. Comparison of STRACO (ST, solid light lines) to KF+RaK (KF, dashed dark lines): RMS and BIAS of MSLP (left) and cloud cover (right).*

Comparisons with the soundings indicate improvements in the scores of relative humidity at lower and upper levels (fig 6) using KF+RaK. On the other hand, the RMS of temperature at 50 km (not shown) are bigger for KF+RaK during the winter period when a cold bias at 500 hPa can be seen. At 20 km (fig 6), the RMS are similar in both configurations but the cold bias is also present in the KF+RaK runs (fig 6). This cold bias could be associated with an underestimation of mid-tropospheric clouds but this needs further investigation. The results of the tests are not completely conclusive for assessing the impact of the model resolution because the size of the verifying area is different at 50 and 20 km, but it seems that the benefits of going to KF+RaK are more clear when the horizontal resolution is increased.

Systematic differences between STRACO and KF+RaK simulations only could be seen in precipitation and cloudiness fields. The contribution of the convective component to the precipitation is larger in STRACO. The amount of low and high level clouds is systematically larger in STRACO than in KF+RaK.

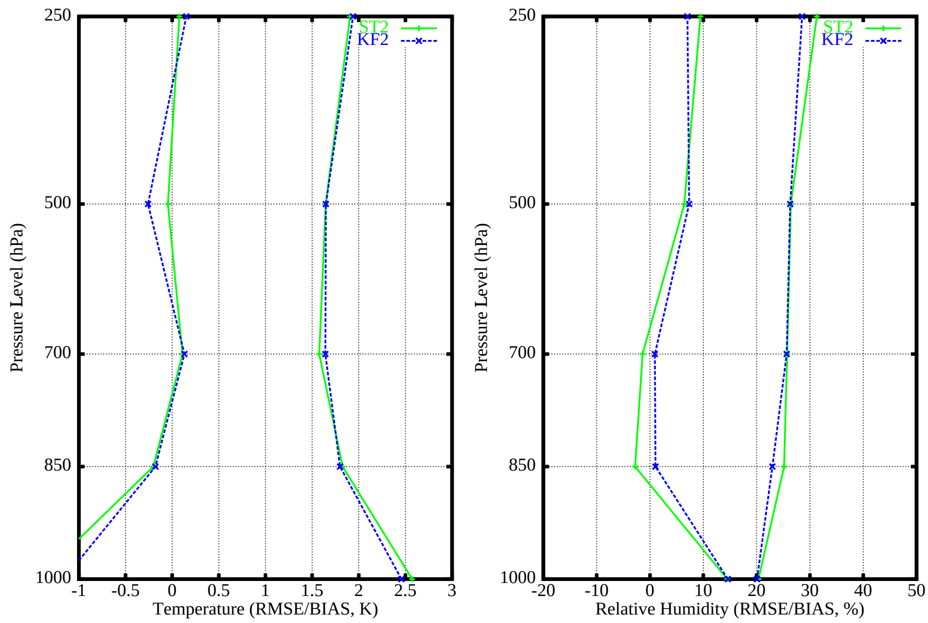

Figure 6: *Objective verification against EWGLAM soundings. Comparison of STRACO (ST2, solid light lines) and KF+RaK (KF2, dark dashed lines) for the 20 km simulations. RMS and BIAS of temperature (left) and relative humidity (right).*

Computer cost

The relative cost of the KF+RaK and the STRACO integrations depends on the resolution. This is because Kain-Fritsch convection is not called every time step but only when the cumulus cloud is expected to change of grid element (at least once every hour). Therefore when the horizontal resolution is increased the convection should be called more often. For the parallel runs performed on the ECMWF's Fujitsu, the KF+RaK forecast took 40 % more time than the STRACO one at 50 km and at 20 km, 200 % more. Similar ratios appear running the model on a CRAY C90. These figures seem to be quite machine dependent since at the SMHI computers KF+RaK and STRACO have similar cost (Ivarsson, personal communication). Nevertheless, the KF+RaK code is currently under development and some optimizations are quite evident.

4 Conclusions

The performance of Kain-Fritsch convection and Rasch-Kristjansson condensation in HIRLAM has been assessed. Comparisons of the new moist physics components with the reference STRACO scheme have been carried out using a typhoon explosive intensification case and some parallel runs. Whereas STRACO was not able of reproducing the typhoon intensification and mesoscale structure, KF+RaK reproduced them (at least qualitatively). From these preliminary parallel runs without assimilation cycle, an improvement on the relative humidity and cloud cover could be noticed, specially going to 20 km resolution. At 50 km little advantage was found using the new schemes.

It seems that the benefits of using KF+RaK instead of STRACO are more clear below 25 km resolution. A very positive feature of a convective scheme is its ability to simulate extreme events. In this sense the performance of KF+RaK for the explosive typhoon development is very encouraging. Looking at the verification of precipitation, K. Ivarsson noticed an improved simulation of extreme precipitation events with the new schemes as well(personal communication). Nevertheless, it is surprising that we did not find a bigger impact of the new schemes on the scores of the model variables for the parallel runs. It seems that the coupling of Kain-Fritsch with other parts of the model, in particular with the radiation and large scale condensation needs to be carefully revised.

5 References

- Calvo, J., 2000: The third COMPARE exercise. Sensitivity experiments using the HIRLAM model *HIRLAM Newsletter*, **35**
- Kain, J. S. and J. M.Fritsch, 1990: A One-dimensional Entraining/Detraining Plume Model and Its Application in Convective Parameterization. *J. Atmos. Sci.*, **47**, 2784-2802
- Nagata, M., L. Leslie, H. Kamahori, R. Nomura, H. Mino, Y. Kurihara, E. Rodgers, R. L. Elsberry, B. K. Basu, A. Buzzi, J. Calvo, M. Desgagne, M. D'Isidoro, S.-Y. Hong, J. Katzfey, D. Majewski, P. Malguzzi, J. McGregor, A. Murata, J. Nachamkin, M. Roch and C. Wilson, 2000: A Mesoscale Model Intercomparison in a Case of Explosive Development of a Tropical Cyclone (COMPARE III). Submitted to *J. of the Meteor. Society of Japan*
- Sass, B. H., 1997: Reduction of numerical noise connected to the parameterization of cloud and condensation processes in the HIRLAM model. *HIRLAM Newsletter*, **29**, 37-45.
- Rasch, P. J. and J. E. Kristjansson, 1997: A comparison of the CCM3 model climate using diagnosed and predicted condensate parameterizations. *J. Climate* , **11**, 1587-1614
- Sundqvist, H., E. Berge and E. Kristjansson, 1989: Condensation and Cloud Parameterization Studies with a Mesoscale Numerical Weather Prediction Model , *Mon. Wea. Rev.* **117**, 1641-1657