Operational use of AROME at Météo-France

Introduction

The operational use of a high-resolution model in Météo-France started in October 2008 with the AROME (Applications de la Recherche à l'Opérationnel à Méso-Echelle) model. An upgraded version (V2) began in April 2010 and further developments for the next version (V3) are already planned.

An important plan to train forecasters was developed before the introduction of AROME. The forecasters were advised to first use the global model to get information on the synoptic context and the forcing, and then the high-resolution model can give useful information on the final parameters and mesoscale features. This concept will be illustrated by an example of a convective situation over France.

In addition to objective measures, a subjective assessment of the model is made by regional and national forecasters. This subjective measures, based on identification of meteorological 'issues', results in a progressive increase in understanding of the model by forecasters and a better knowledge of its strengths and weaknesses.

Finally a meeting took place in Toulouse during February 2009 between forecasters and model researchers to draw up a balance sheet of these two first years of model operational use.

Recent AROME version and future developments

Global Overview of the Météo-France Forecasting System

The global model ARPEGE is run every six hours (102 hours forecast) with a coupled regional model ALADIN (54 hours forecast) and a high resolution model AROME (30 hours forecast). The main characteristics of these models are detailed in Figure 1.

Recent developments of AROME

Version 2 of AROME has been operational since 6 April 2010. One major difference from version 1 is the fact that AROME is now directly coupled to the global model ARPEGE, and no longer to the regional model ALADIN. The main reason for this change is the fact that the resolution of ARPEGE over France is now 10 km (not far from the ALADIN resolution of 7.5 km) and the simplification of the operational computational process with a 15 minutes gain of time in AROME availability.

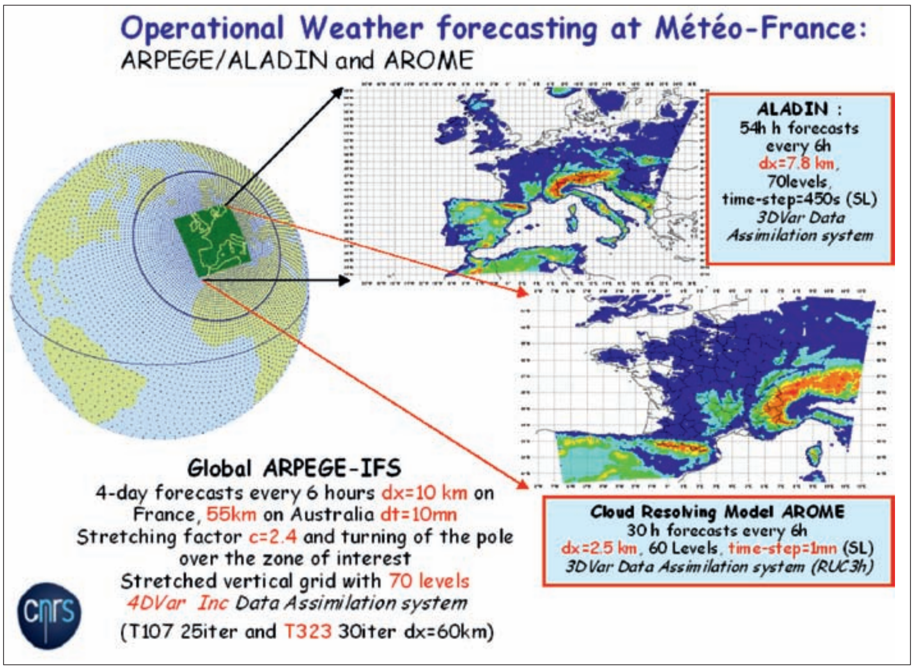


Figure 1

Operational models running at Météo-France

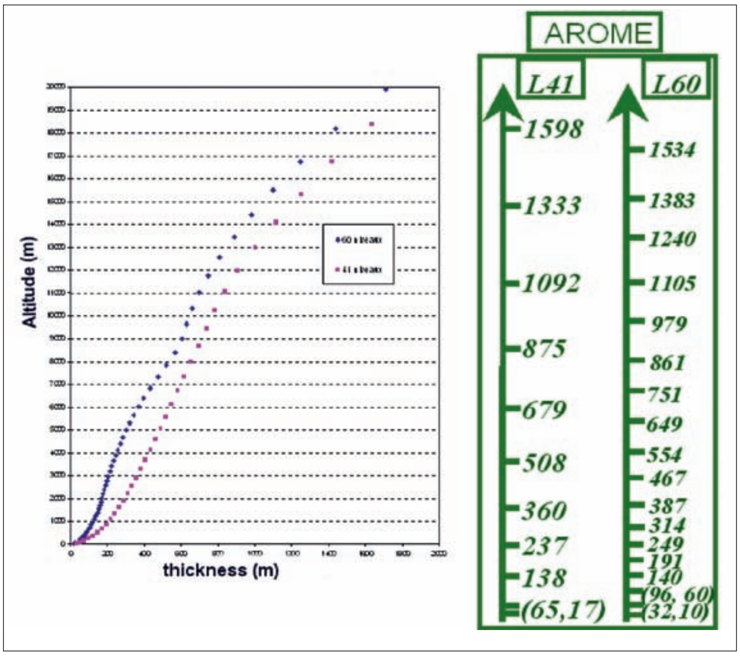


Figure 2

Thickness of layers in AROME (V1 L41 and V2 L60)

This change has a neutral or positive impact on model performance as measured by verification scores.

Another difference bet-ween V1 to V2 is the increase of vertical resolution from 41 levels to 60 levels. The added levels are situated mainly at low levels: the first level is now at 10m in V2 compared to 17m in V1. 27 levels are implemented below 3000m in V2, compared to 15 in V1 (see Figure 2)

Reflectivity Assimilation in V2

Radar reflectivity cannot be assimilated directly by the model. The process used consists of turning reflectivity into a specific humidity increment: an increase in case of precipitation observed but not forecast, or a decrease in case of precipitation forecast but not observed.

In the example of 8th October 2008, AROME - without reflectivity assimilation - missed the squall line in the South-East of France. With reflectivity assimilation, a positive increment of specific humidity is added in the area of precipitation at 06 UTC (see the orange ellipse in Figure 3) which enables the model to generate a strong squall line of bow-echo type three hours later.

Future developments of AROME (V3)

A strong requirement from forecasters is to enlarge the domain in order to better anticipate and describe perturbations coming from the south and west of France. Figure 4 shows the future enlarged domain, increased in area by 70 %.

The next version of AROME will also add hail in the microphysics transformation (see figure 5). That should help the difficult forecast of hail reaching the ground in thunderstorm situations, and should also improve the simulated radar reflectivity of the current model which can't reach the highest values observed in the radar network in the case of melting hail in clouds.

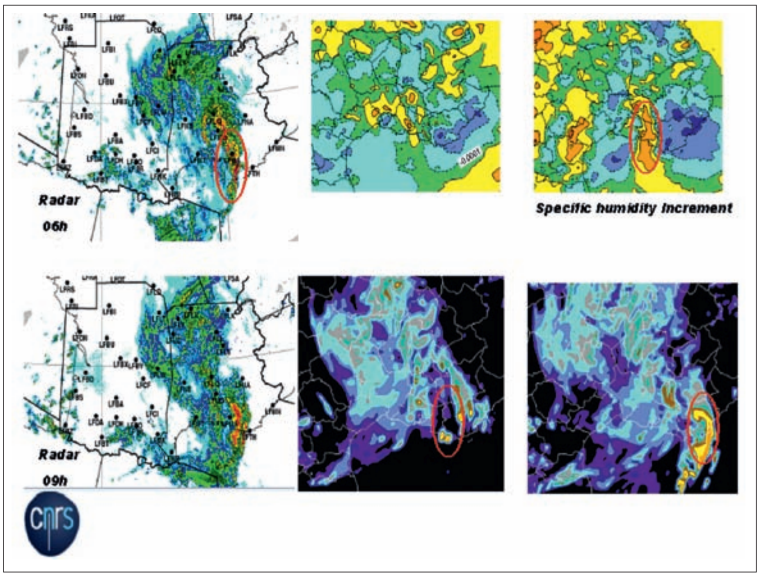


Figure 3

Radar reflectivity at 06-09 UTC on 2008/10/8, and simulated reflectivity without and with specific humidity increment

Evolution of statistical cloud scheme in AROME

The description of the subgrid variability in cloud cover is given by a probability function which depends on the intensity of turbulence. In some cases with stable and cold atmosphere, there is currently an underestimation of low cloud cover when the relative humidity is high. To correct this default, another term will be added in the equation of

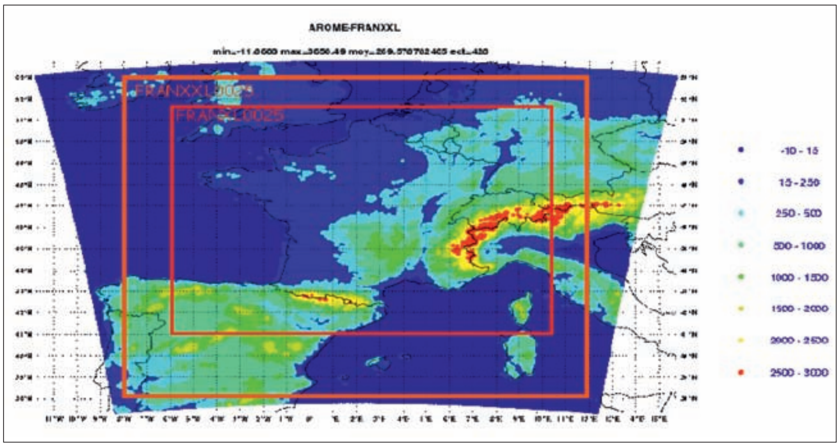


Figure 4

The current and future domain of AROME

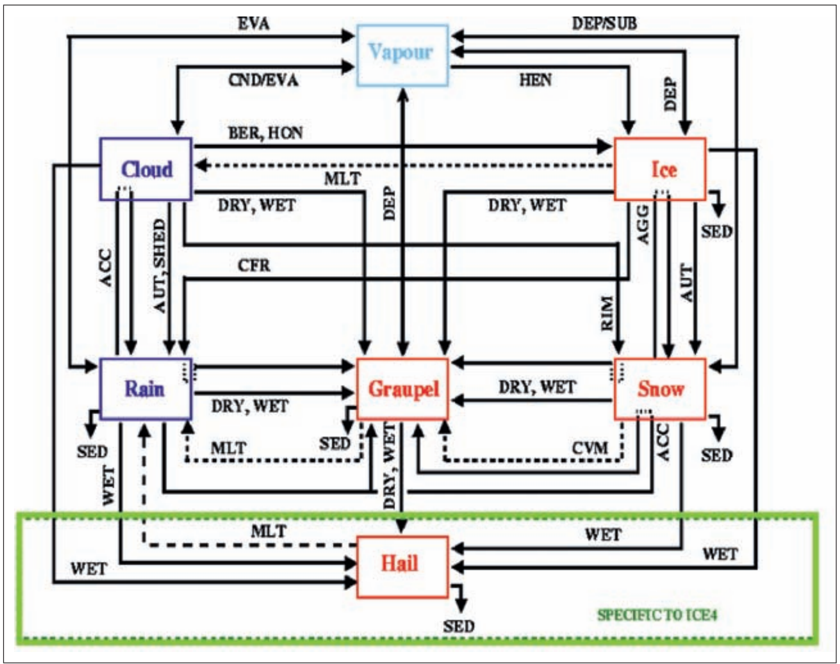
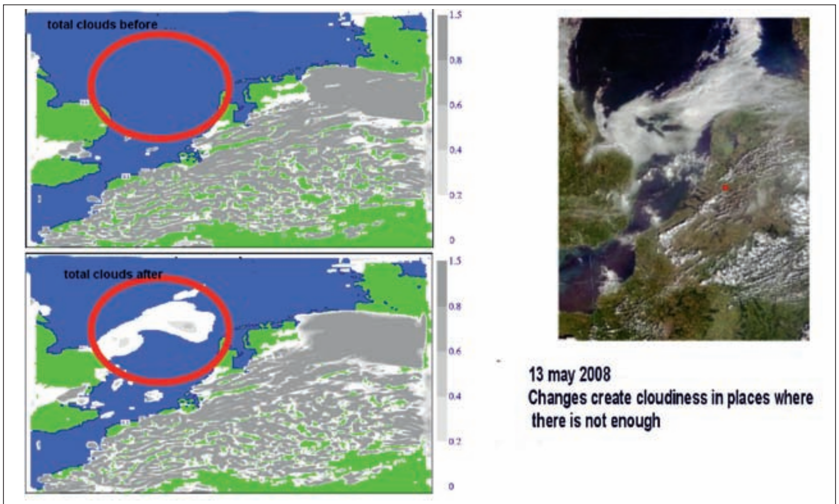


Figure 5

The microphysics scheme in AROME with the future addition of hail in green.



nebulosity which depends on a critical moisture profile. This change was suggested by a study of Wim de Roy from Netherlands (Hirlam Newsletter November 2010 page 21-29).

Figure 6 below shows the positive impact of this change in the red ellipse for the example of 13 May 2008.

Example of AROME Outputs in a Convective Situation

The synoptic context of 13th May 2009 is summarized by the ANASYG graphic chart in Figure 7 which includes both surface and upper-air features.

A strong south-westerly flow at altitude from Spain to France is indicated by the jet with diffluence at the exit. An active PV anomaly in upper levels interacts with warm air in low levels and produces an area of deep convection in the South-West of France. After this synoptic analysis of the situation, the question for the forecaster is to qualify the severity of the convection. If severe and organized convection is expected, then warnings are required. Aid to answering to this question can be found in AROME forecast reflectivity (see Figure 8)

Figure 6

forecast of cloudiness before and after changes in cloud scheme where strong thunderstorm cells move quickly from the Gulf of Biscayne across the South-West of France. Notice that each successive run of AROME before and after the 18 UTC run forecast the same type of convection, so this kind of poor man ensemble prediction provides a good confidence for the occurrence of heavy thunderstorms.

The comparison of the forecast reflectivity with the radar observed reflectivity (see Fig 9) shows a quite realistic forecast in spite of some delay in the convection starting up. There is also an under-estimation of reflectivity intensity, which can be explained by the lack of hail in the model's microphysics, so the simulated reflectivity can't reach the highest intensity observed in case of melting hail in thunderstorms.

The 18 UTC run of AROME simulated the same shaped bow echo as observed at 02h30 UTC north-east of Bordeaux, where observations reported hail and very strong gusts (see Figure 10). The forecas-ter, with the knowledge of the conceptual model of bow echo which is a very active type of squall line, had therefore a strong argument for issuing warnings in the area.

This situation is a good example of the value added by AROME to global models in the description and behaviour of the convection : it

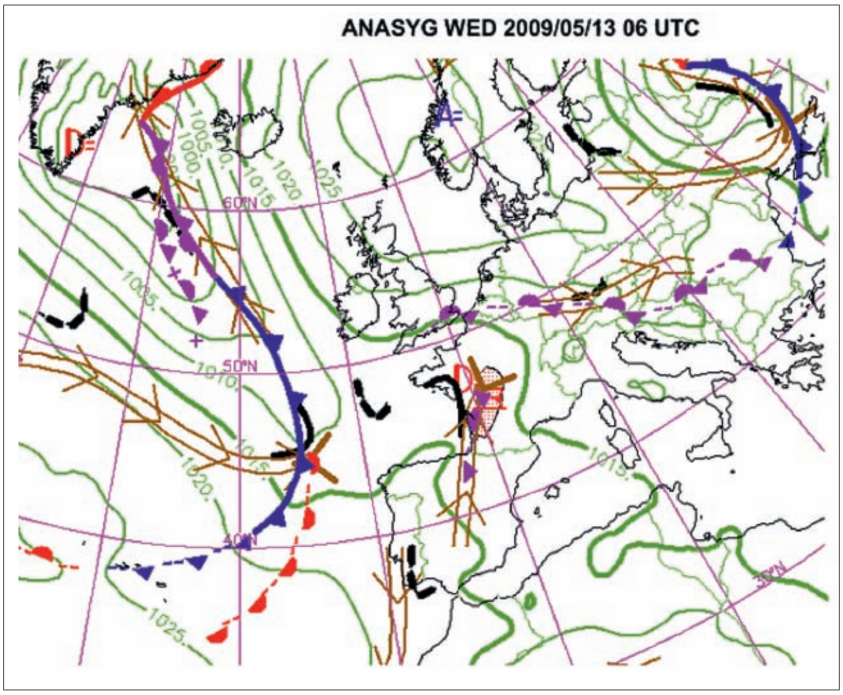


Figure 7

ANASYG 06 UTC 2009/05/13

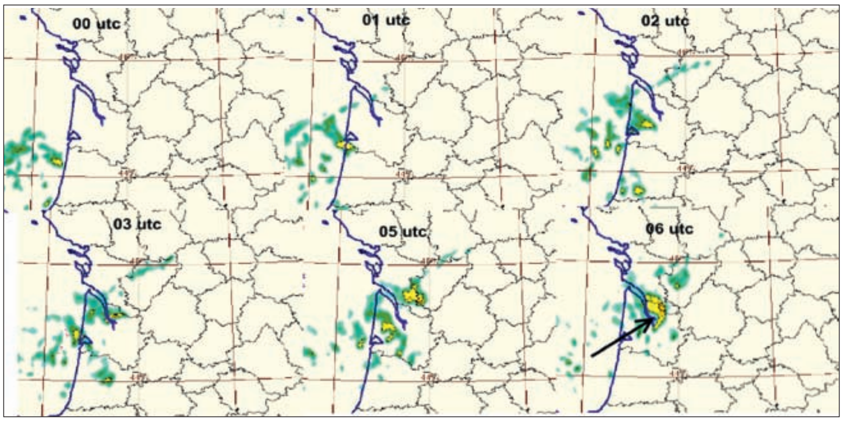


Figure 8

Forecast reflectivity by AROME run 2009/05/12 18 UTC

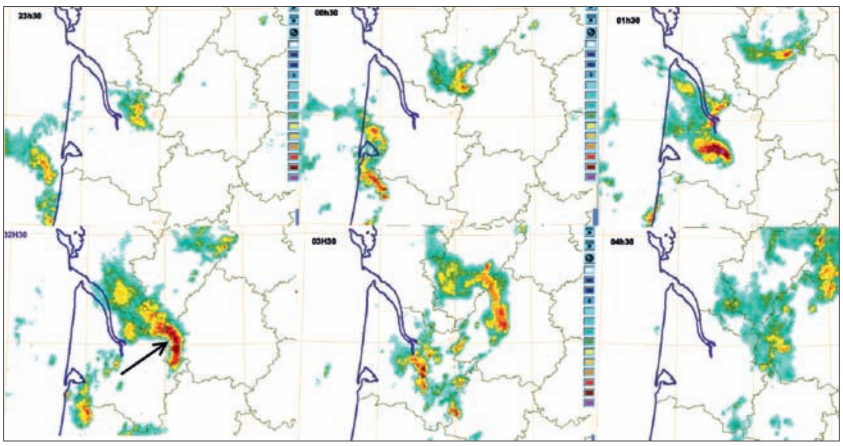
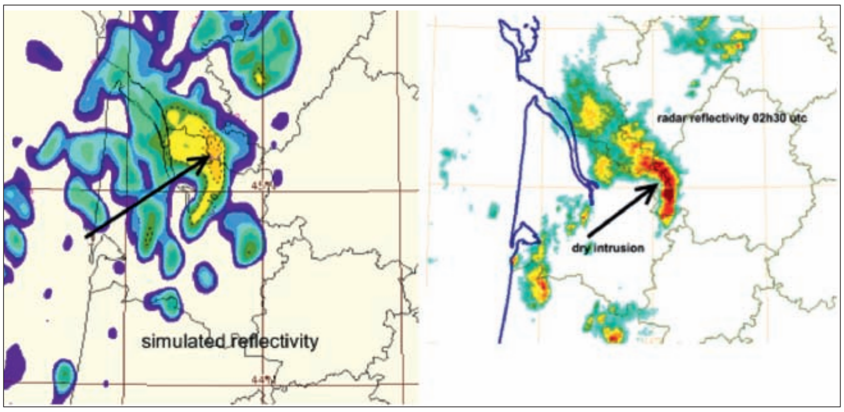


Figure 9

Observed reflectivity on 2009/05/12



◀ *Figure 10*

Simulated reflectivity by AROME (left) and observed reflectivity (right) focused on the bow echo

suggested fast moving thunderstorms cells and possible organization of a bow echo - a very active type of severe convection – and was very helpful to the process of issuing warnings.

AROME Verification

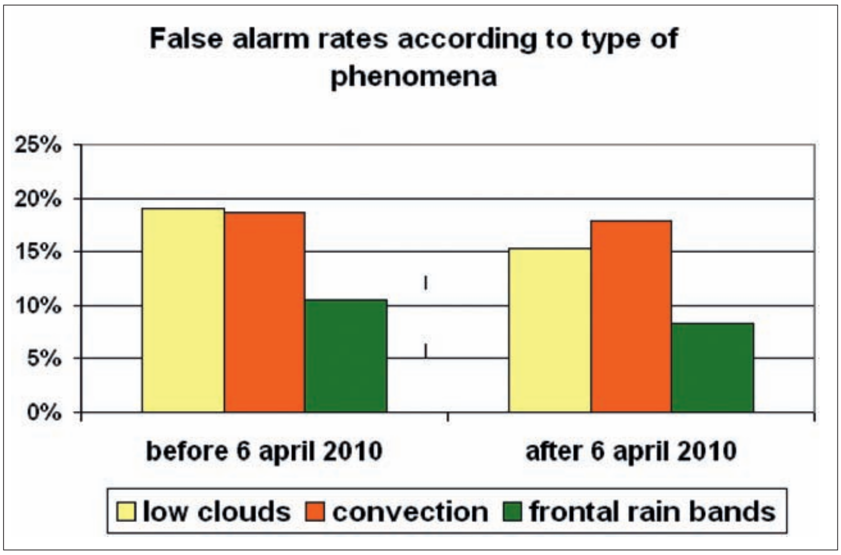
Objective Measures

As with any operational model, AROME is monitored using objective performance measures. Specific tests like "Brier Scores" are performed to avoid the double penalty effect which could affect high resolution forecast when the area of highest values observed are correctly forecast but often shifted from their actual position.

For example, these measures show a positive contribution of AROME compared to ALADIN for the summer convection and for convective cloud coverage.

▼ *Figure 11*

ratio of false alert according to different parameters



Subjective Assessments

A very important subjective assessment is made in each of the seven meteorological regions and in the central office forecast in Toulouse. This is based on the concept of 'meteorological issue' of the day. This means that each day the forecaster focuses on what is interesting in the situation from a forecast point of view. A wide range of issues are available: fog, low clouds, breezes or local winds, synoptic or regional winds, snow, frontal structure, orographic structure, organization of convection, etc. The chosen issue is entered in a database via a web interface and the assessment of the accuracy of the forecast in relation to the selected issue is done by another forecaster afterwards.

For each issue entered in the database, the forecaster must specify his degree of confidence in the forecast of AROME. The confidence scale ranges from very good to very low through "I do not know". Comparing the distribution of trust between the periods October 2008-March 2009 and May 2009-April 2010 shows a significant decrease in the proportion of "I do not know" responses. This indicates that the forecasters are gaining a better knowledge of the characteristics, strengths and weaknesses of the models.

Examples of subjective control results

The data base allows to determine the proportion of goodforecast and false alert for various parameters (see figure 11) . It gives useful informations on the impact of model changes from the forecaster point of vue. It is for example interesting to notice that the major changes in AROME in April 2010 have resulted in a decrease in false alerts according to forecasters.

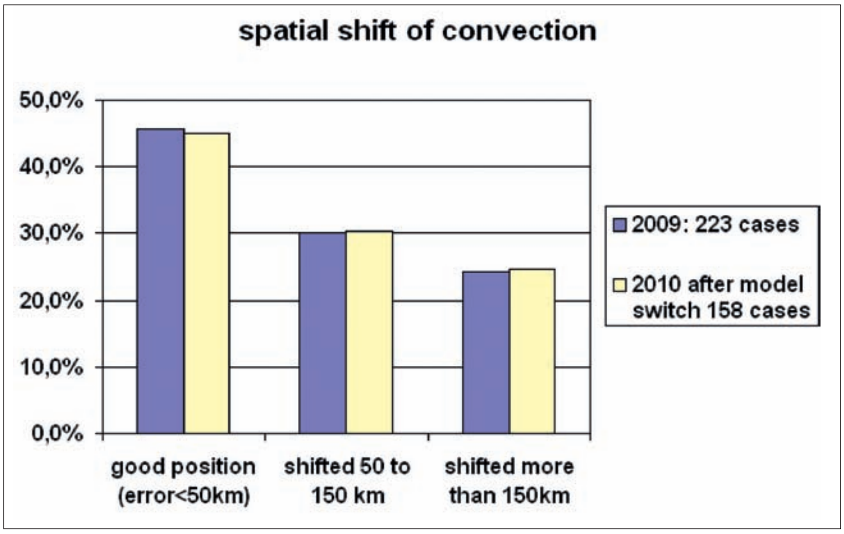


Figure 12

spatial shift of convection in subjective controls

The database is sufficiently detailed to investigate certain meteorological issues rather finely.

For convection, spacial shift based on the type of convection, time lag for the beginning and end of convection can be analyzed. For low-level phenomena, the error in areas affected by fog or low clouds, start and dissipation of fog can be analyzed.

Figure 12 beside shows the results for spatial shift of convection: three out of four, convection is properly seated near 150 km.

Conclusion

Analysis of the two last years of operational running of AROME confirms a positive use of the model by forecasters. Convincing results come from the forecasts for convection. Both objective and subjective measures show good behaviour of the model when forecasting convective storms. AROME gives good information on the type of convection and risks including heavy precipitation, while the number of false alerts remain rather low. However, there is sometimes some inconsistency between successive runs with illusory details in convection organization. Subjective measures are an important element contributing to a better use of the model by forecas ters. They also provide useful feedback to researchers on the model behaviour: for instance, the improvement in V2 AROME for fog and low cloud forecasts has been notice by forecasters although it is more difficult to identify using objective measures.

Bernard **Roulet**
Meteo France

References

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