Test and potentialities of a new numerical weather forecasting non-hydrostatic model for hydrology and snowcover simulations

I. Dombrowski-Etchevers[1], L. Quéno[1], F. Karbou[1], J.-F. Ribaud[1/2], Y. Durand[1] ,
[1] Météo - France/CNRS, CNRM - GAME UMR – 3589/Grenoble/France
[2]Météo - France/CNRS, CNRM - GAME UMR – 3589/Toulouse/France

ABSTRACT : In the framework of the avalanche hazard estimation, Météo-France has used an automatic suite since the early 1990s which simulates meteorological parameters (SAFRAN), snow cover stratification (Crocus), and avalanche hazard (MEPRA). This system merges several sources of information as different mountainous observation networks and outputs of the French NWP model ARPEGE (about 15 km mesh size). The outputs are provided at various elevations, aspects, and slopes for different mountainous French massifs. However, a new NWP model AROME has been operational since December 2008. This model differs from the previous atmospheric model by its finer resolution of 2.5 km over France and its non-hydrostatic scheme. AROME is thus an interesting tool to anticipate severe weather conditions, heavy precipitation and orography related phenomena. We thus plan to use it soon to improve our current avalanche hazard diagnostics and this study will show the first step of this evaluation process. In this study, we mainly evaluated the AROME model in alpine areas with a focus on "Alpine snow and risk". We first examined precipitation; a key-parameter for snowcover simulations. We compared the daily precipitation forecasted by AROME versus different rainfalls spatialization systems. One of these was the SAFRAN system, specifically developed for mountainous areas, and we focused mainly on 50 measurement reference points in French Alps. All comparisons were made globally over the whole French Alps, but also by dividing the Alps into four sub-areas climatologically homogeneous. The results show an overestimation from 8 to 25% in the AROME fields according to the different references. Secondly, we compared the forecasted AROME moistures that impact the snowpack via the latent heat flux and via the solar and infrared radiation with the occurrence of clouds. On the one hand, the integrated water vapor (IWV), which can be closer to precipitation, was evaluated versus GPS observations. On the other hand, the surface relative humidity was compared versus meteorological measurements and SAFRAN reanalyses. The results showed an overestimation of the surface humidity growing with the altitude (from 2 to 9%) and a deficient diurnal cycle at mid elevation; the integrated water vapor being systematically underestimated. Currently this evaluation continues in focusing on surface temperature.

KEYWORDS :weather forecasting, meteorology,hydrology, snow, .

1 INTRODUCTION

The prediction of avalanche risk (PRA) and the implementation of innovative tools for its numerical modeling are among the highest priority objectives of the CEN. Currently, avalanche risk forecasters routinely use SAFRAN-Crocus-MEPRA models as tools for PRA. The SAFRAN (Durand et al, 1993) model fed by meteorological short-range forecasts from ARPEGE provides, in hourly basis, the relevant parameters for the snowpack model Crocus (precipitation, temperature, wind, humidity, radiation, cloud cover).The main assumption of this system lies in the spatial homogeneity of the massifs involved (especially for precipitation) which implies a corresponding working scale and excludes representing all the local effects such as those due to accumulation and erosion by the wind. The SAFRAN outputs are produced per homogeneous massifs for several directions and altitudes. Using these parameters as inputs, Crocus (Brun et al, 1992) simulates and evolves the snowpack on these homogeneous zones by elevation, exposure and slope. Finally, the expert system MEPRA (Giraud, 1992) estimates the avalanche risk, whether natural or accidental, per massif, elevation, slope and exposure. This configuration is completely compatible with the use of a global model outputs. However, this configuration becomes questionnable when one wishes to use meteorological information at a higher spatial resolution. Since December 2008, the limited-area model AROME becomes operational at Météo-France. This model differs from the other atmospheric models by it fine resolution of 2.5 km over France (Seity et al, 2011). AROME provides forecasts from 3 hours to 30 hours ranges to anticipate severe weather conditions such as thunderstorms and heavy rain. Thanks to its numerous advantages, the AROME model is highly relevant to improve the meteorological forcing of the snow model Crocus. For the present work, we first evaluated the AROME model in alpine areas. This is the first time that such an assessment is undertaken with a focus on "Alpine snow and hydrology".

2 MODEL AND DATA

2.1 AROME, a new forecast model

AROME is the most recently operational numerical weather prediction model at Météo France. The dynamical core is derived from the ALADIN model but tailored to finer scales and the physical parametrizations are inherited from the Méso-NH research model.

Because of the extremely variable spatially and temporally character of precipitation, we used estimates for 06 UTC and 30 UTC from the 00 UTC run for the precipitation, so we got the forecasts of daily precipitation. To know the AROME respect to the diurnal cycle of moisture behavior, we used hourly forecasts of moisture cycle 6 UTC model.

2.2 DATA for comparisons

The forecasted precipitations were compared with two precipitation analysis and spatialisation systems ANTILOPE J+1 (Météo-France) and SPAZM (EDF-DTG, Gottardi et al, 2012) and the SAFRAN reanalyses for 50 measurement reference points. The comparision is possible only if the altitude difference is inferior to 300 meters.

The forescasted moisture was compared with GPS observations (Integrated water vapor), the measurements points and the SAFRAN reanalyses for fivety points. The comparision with the four most closed points is possible only if the altitude difference is inferior to 300 meters.

3 PRECIPITATION

The figure number 1 represents the monthly precipitation forecasted by AROME and reanalysed by SAFRAN [Durand et al., 2009], for 50 measurement reference points and divided into four sub-areas climatologically homogeneous. We find an over-estimation of rainfall of AROME for Central Alps (average 126mm/mois against 94 mm / month, or 34% error). The statistical bias is substantially identical to the Northern Alps. In contrast to the Southern Alps and the Far East, the averages are very close, but AROME strongly underestimates the precipitation of winter months.

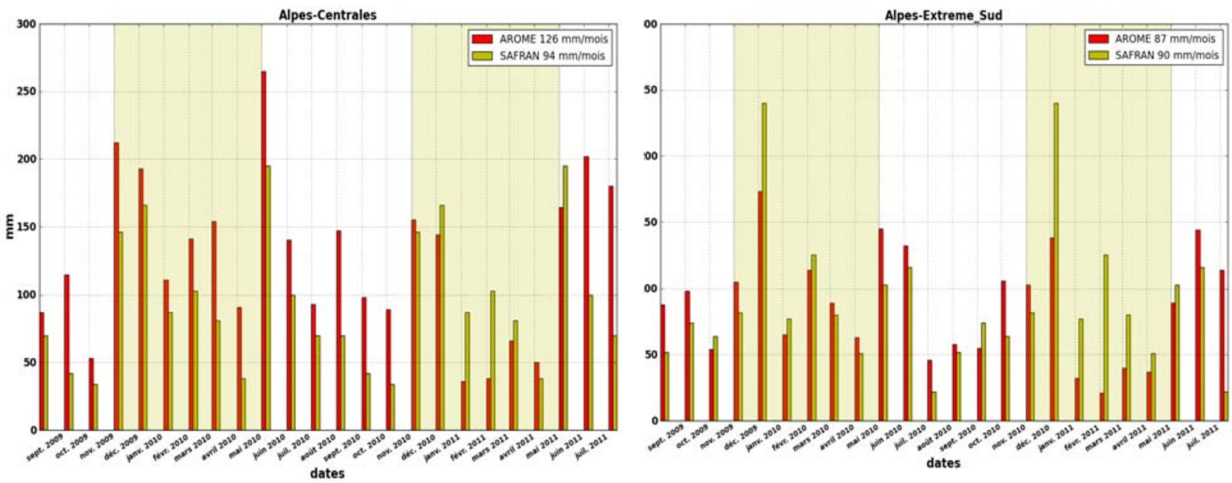

Figure 1 :Monthly precipitation totals in mm under AROME and reanalyzed by SAFRAN. Right: Central Alps. Left: Far South Alps

4 MOISTURE

The integrated water vapor content of the air column is a good indicator of potential precipitation ([Trzpit, 1980]), useful for example for forecasting heavy precipitation ([Boniface, 2009]). In addition, as an estimate of the total tropospheric humidity, IWV may provide an

indirect indication of the effect of the AROME prediction on infrared radiation. Water vapor absorbing a large part of this radiation, an overestimation of the IWV may imply an underestimation of the infrared radiation (and vice versa).
Figure 2 shows the comparison between the IWV under AROME and that measured by GPS stations in France and Switzerland. It was found that the annual cycle is less pronounced at high altitude either to the observations for forecasting. AROME has a consistently negative bias of up to 2mm.

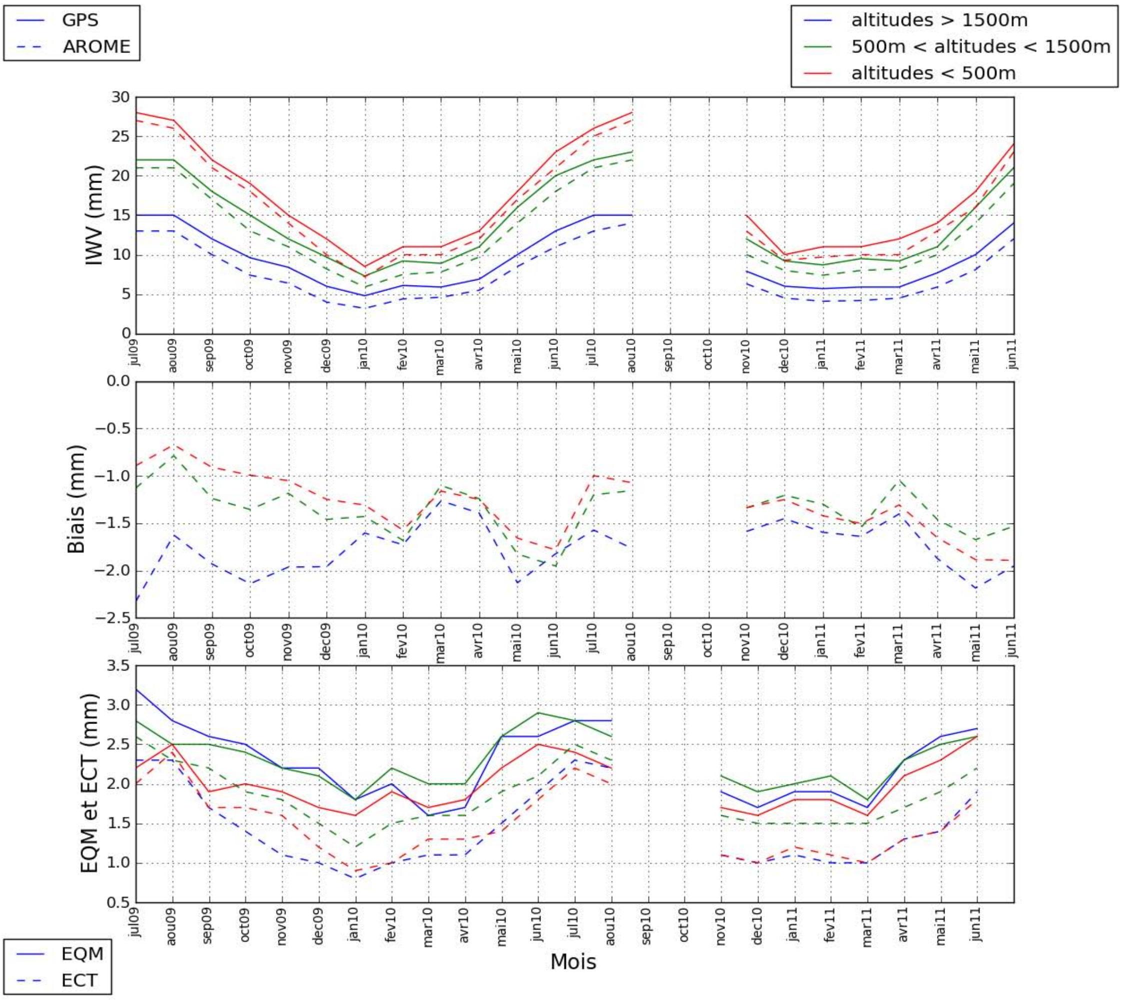

Figure 2 : Monthly average prediction to 6 UTC IWV (mm) and comparison scores AROME / GPS by month, depending on altitude of 48 stations for the period 01/07/2009 -30/06/2011.

Regarding the air moisture we compared AROME forecasts, SAFRAN reanalysis and observations for 8 common points of measurement. We note that for the automatic stations (nivôse), such as the Ecrins (Figure 3 left), SAFRAN reanalysis are closer to observations that AROME forecasts. However for the snow and weather stations (Figure 3 right, La Plagne, for example) the AROME forecasts are close to SAFRAN reanalysis. This can be explained by the fact that the SAFRAN reanalysis uses hourly data of the nivôses stations, whereas they have only two daily data for the snow and weather stations. We can be satisfied with the AROME performance in averaged monthly air relative humidity.

Figure 4 shows the diurnal cycle in Chamonix and Aiguilles Rouges. The diurnal cycle is more or less good represented by AROME according to altitude. The valley is too deep for the AROME grid can reproduce this escarpment. The valley bottom in the model is higher than the real relief. Therefore, the daily cycle of forecasted relative humidity is a high profile Mountain type in Chamonix. The statistical bias reaches 25% in Chamonix, and only 8% in the Aiguilles Rouges, whose elevation model is closer to real relief.

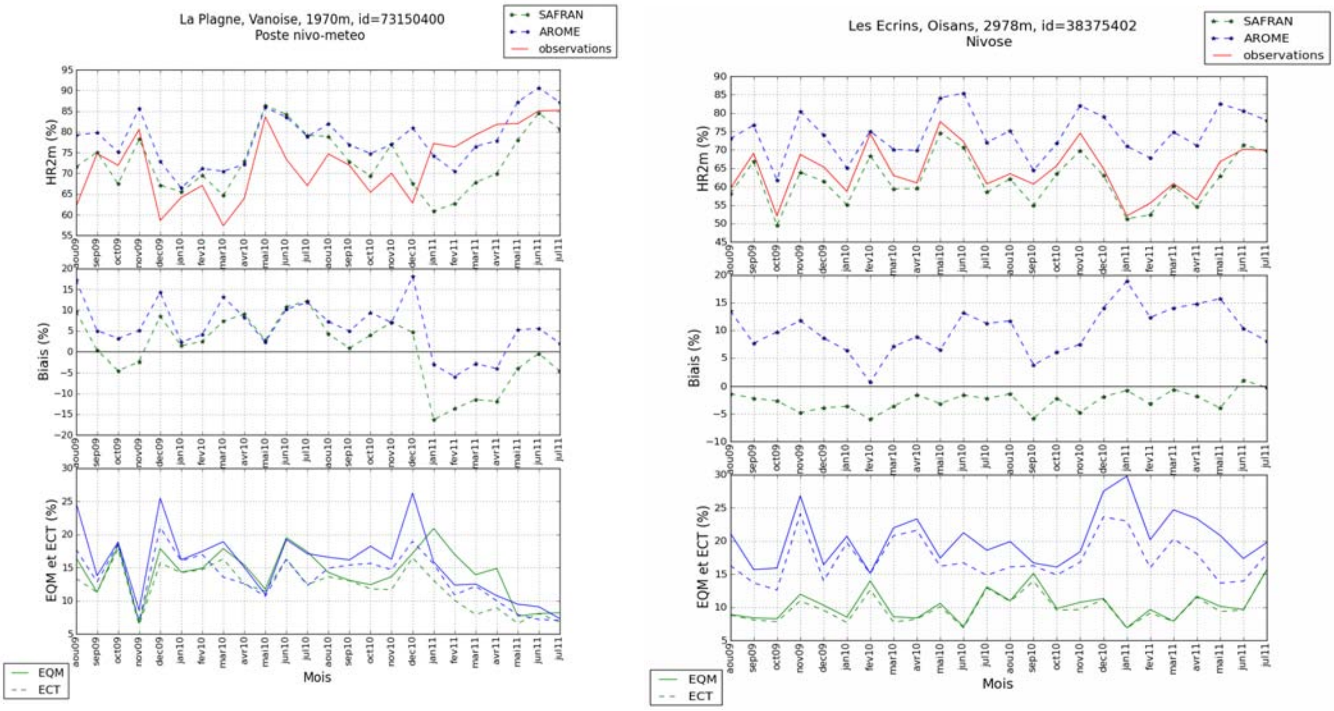

Figure 3 : Annual cycle of the relative humidity of the air and scores a nivôse and a nivo_meteogical station AROME versus SAFRAN versus observations for the period 01/08/2009 - 31/07/2011.

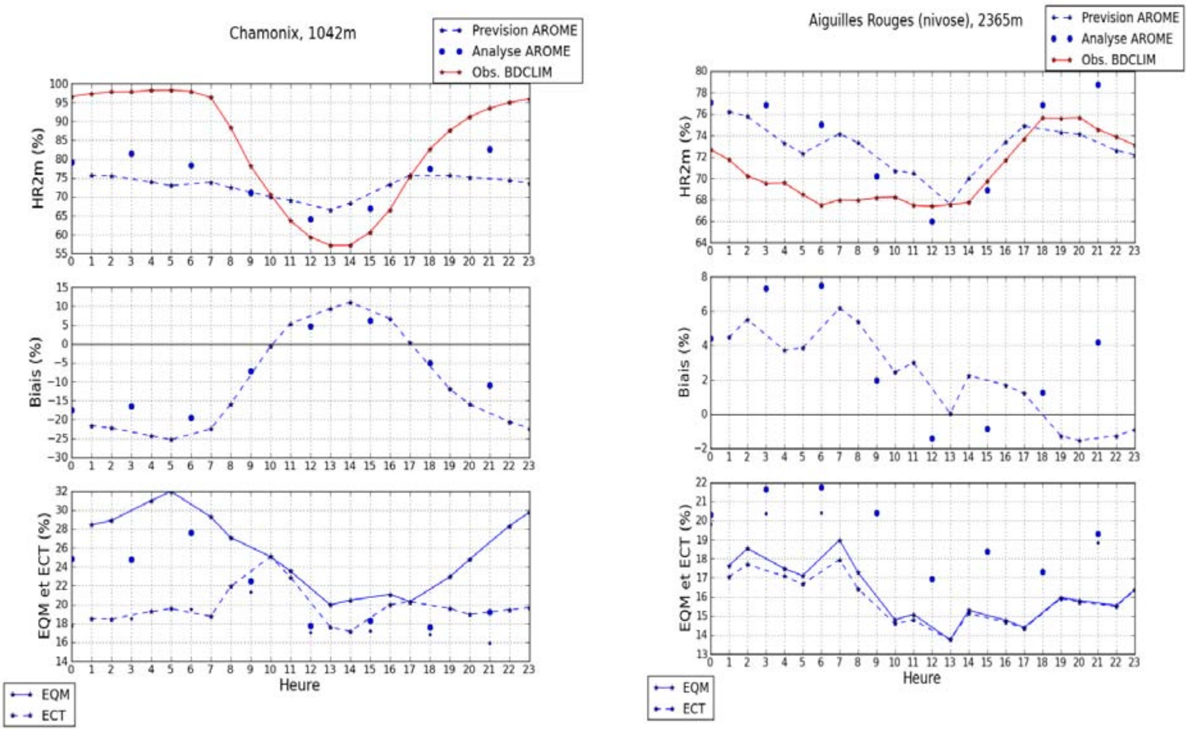

Figure 4 : Daily cycle HR2m (g.kg-1) and scores AROME versus Observations in the Chamonix valley for the period 01/08/2009 - 31/07/2011.

5 DISCUSSION AND CONCLUSION

The goal of this first evaluation of atmospheric model AROME was to quantify its behavior forecasts for the daily rush and the humidity of the air:

For precipitation, AROME provides monthly precipitation totals and the number of days with precipitation, but with a slight overestimation compared to the analysis system, SPAZM.

The comparison against SAFRAN points positions is more severe: AROME tends to rush too north of the French Alps, while in the Southern Alps and extreme south, there is a lack of rainfall sometimes important especially during the months of winter. If the defect is confirmed, it should be taken into account because winter precipitation in the mountains are often snow accumulation and underestimated may cause an underestimation of the risk of avalanche.

A study in progress, with further impact on the snowpack and focused on some positions will better understand the AROME behavior. In addition, to improve the forecasting of precipitation AROME, it is planned to use a correction factor according to altitude of SAFRAN. This would correct the errors due to differences in relief. This has already been tested and analysis has yielded very encouraging results.

In terms of moisture, AROME-overestimates systematically the IWV of 2mm, while it underestimates of about 5% relative humidity. These scores are comparable to the error of observation. However, when the model relief differs too from real relief AROME poorly reproduces the diurnal cycle. Apart from this exception, AROME provides good moisture and well forcing SURFEX/Crocus (Vionnet et al., 2012) for cloudiness and impact over the infra-red radiation

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