TO THE ORIGIN OF THE TEMPERATURE BIAS IN THE AROME NUMERICAL WEATHER FORECAST MODEL : INVESTIGATIONS AT A HIGH-ALTITUDE SITE

Isabelle Gouttevin[1]*, Vincent Vionnet[2], Fatima Karbou[1], Hugo Merzisen[1], Yannick Deliot[1]

[11] Univ. Grenoble Alpes, Université de Toulouse, Météo-France, CNRS, CNRM, Centre d'Études de la Neige, Grenoble, France
[2] Centre for Hydrology, University of Saskatchewan, Saskatoon, Canada

ABSTRACT: The AROME-France meso-scale atmospheric model currently provides operational weather forecasts at about 1.3-km spatial resolution over a domain covering France and parts of the surrounding countries. In particular it covers the French Alps and Pyrénées. Recent studies dedicated to the evaluation of the potential of the high-resolution analysis and forecast field of AROME for snow-related applications have highlighted significant biases in the surface temperature and relative humidity fields, with a marked diurnal cycle and increasing amplitude with altitude (Vionnet et al., 2016; Quéno et al., 2016; Dombrowski-Etchevers et al., 2017). Here, we make use the thorough set of meteorological and surface observations routinely collected at the high-altitude observatory Col du Lac Blanc (French Alps, 2720 m a.s.l., Apes d'Huez ski resort) to diagnose the origin and implications of this temperature biais in AROME. Among others, the possible contribution to this bias of an erroneous radiation budget, and of uncertainties in the snowpack thermal modelling, are considered by means of comparisons to observations and appropriate numerical experiments. This diagnostic will ultimately help improve weather forecast in mountain regions, of benefice for a variety of applications including avalanche forecasting and mountain hydrology..

KEYWORDS: Numerical weather prediction models – Mountain meteorology – Model biases.

1. INTRODUCTION

AROME is a meso-scale atmospheric model, currently providing operational weather forecasts at about 1.3-km spatial resolution over an extended French domain. Over the mountain ranges Pyrénées and Alps, meteorological forecast currently used by the operational avalanche warning system is provided by a lumped analysis and forecast scheme (SAFRAN, Durand et al., 2009) operating at the scale of mountain chains ranging from 500 to 2000 km^2. AROME forecasts could beneficially be used as input to a future, spatially distributed avalanche warning system, provided a sufficient accuracy of its meteorological fields is reached.

The present study evaluates AROME fields against observations from the high altitude Col du Lac Blanc site (CLB, 2720 m a.s.l.) and describes a strategy to identify the origin of AROME biases. It constitutes a re-assessment and extension of previous studies (Vionnet et al. 2016; Quéno et al., 2016; Dombrowski-Etchevers et al., 2017) which notably revealed substantial negative biases in 2-m air temperature and incoming longwave radiation in an older version of AROME. Major changes to AROME in spring 2015 regarding the data assimilation system, the horizontal and vertical resolutions, the considered topography and the coupling to the surface scheme (Brousseau et al., 2016) make it timely to reassess the performance of AROME in mountain regions.

2. DATA

2.1. AROME fields

We make use of the 12 first hours of the UTC00 and UTC1200 hourly AROME forecast fields (surface variables only) extracted at the location of the CLB (45.13°N, 6.12°E) for the 15/10/2016-30/7/2018 period.

2.2. Observations

The observations acquired at the CLB site and used for the present study are : shortwave radiation incoming to the surface (swin), longwave radiation incoming to the surface (lwin), air temperature (t2m m), relative humidity (rh).

All observations are natively acquired at 10 min resolution and then averaged to hourly resolution for comparison to AROME fields. T2m and rh are actually measured respectively at 6 m (3.2 m) above snow-free ground, which makes up for a height above the snow surface within 50 cm of 2 m for t2m during the 2018-01-15 to 2018-05-01 period that encompasses most of the snow season.

Swin and lwin data have been carefully filtered for periods when sensor covering by water or snow could be suspected.

3. METHODS

Observed and model fields are compared at CLB using standard statistics : mean bias (MB) and standard deviation of error (STDE). A focus is placed on the diurnal cycle and the seasonality of the biases, and on their understanding in the light of physical processes like night-time radiative loss and temperature inversions over snow-covered areas.

In a second time, off-line simulations of the surface conditions at CLB are carried out (Table 1) to disentangle the likely contribution to the bias in t2m of :

- inaccuracy of the AROME forcing (ATM)

- the complexity and nature of processes resolved by the AROME-default snow scheme (SNO). The latter is done by substituting to the AROME-default snow scheme the more advanced, multi-layered snow scheme Crocus (Vionnet et al., 2012) in the off-line simulation.

Experiment	**Forcing**	**Snow scheme**
REF	AROME	AROME-default
ATM	OBS	AROME-default
SNO	AROME	Crocus

Table 1. Numerical experiments performed to disentangle the origin of AROME bias in t2m

4. PRELIMINARY RESULTS

For this extended abstract we expose first results that concern the bias analysis only. The results from off-line simulations will be presented in poster form during ISSW.

As already revealed by previous studies, AROME exhibits strong negative biases on clear-sky winter days, with a marked diurnal cycle characterized by a stronger bias at nighttime (see Figure 1). Although the amplitude of this bias reduces towards the summer season, its diurnal cycle and the ranking between dry vs humid conditions persist. The snow-free October 2017 appears as the only period with daily mean bias lower than 1°C (see Figure 2), which may also be due to the specific conditions of the short period considered (only 15 days).

Lwin are fairly underestimated by the model all around the year (Figure 2, Figure 3), but minimal underestimation (around 12 W m^{-2}) occurs during the low-insolation months Dec-Jan when no marked diurnal cycle of the bias nor difference between humid and dry periods is observed. Conversely, the mean lwin daily bias increases up to -30 W m^{-2} in late winter and spring on days when humid conditions are observed, while being around -22 W m^{-2} for all-sky conditions. During these months the model tends to underestimate the occurrence of cloudy periods as revealed by the comparison between observed and modelled swin. In June, and to a lesser extent in July, convection develops with one to two hours advance in the model with respect to observations : this leads to a characteristic reduction in the lwin bias in early afternoon (Figure 3).

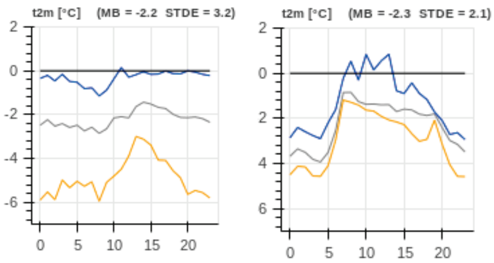

Figure 1: AROME diurnal bias in t2m in Jan 2018 (left) and July 2018 (right) for all conditions (grey), high humidity conditions (blue, rh > 80 %) and low humidity conditions (yellow, rh < 80 %).

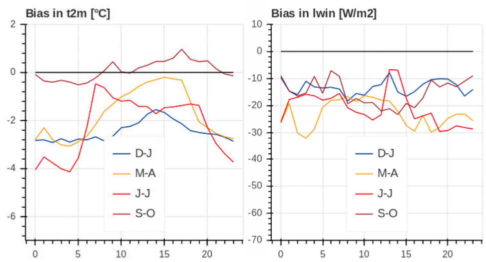

Figure 2: Seasonality of the diurnal bias in t2m and lwin (D-J : Dec-Jan; M-A: Mar-Apr; J-J:Jun-Jul; S-O: Sep-Oct).

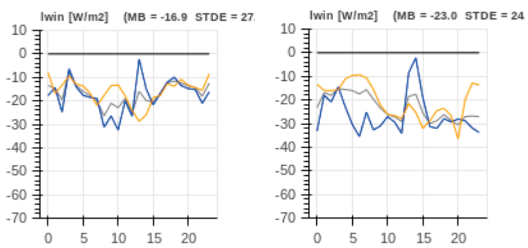

Figure 3: Same as Figure 1 but for bias in lwin.

5. DISCUSSION AND CONCLUSION

The marked diurnal cycle of the t2m bias and its prevalence on clear-sky winter days likely denotes exaggerated temperature inversions over snow surfaces in the model, produced by intense radiative cooling at the snow surface and stable conditions. Such stability conditions also tend to develop after snowmelt on clear-sky nights, making up for a marked diurnal cycle of the t2m bias even in July when snow has already melted. Decoupling between surface and atmosphere under very stable conditions has been a long-lasting issue of atmospheric and surface modelling (e.g. Martin and Lejeune, 1998) and developments are underway to circumvent it.

On a second hand, the inability of the original, one-layered snow scheme of AROME (AROME-default in Table 1) to properly resolve the temperature profile and thermal properties within the snow, may contribute to an exaggerated radiative cooling of the snow surface. This likely source of bias will be investigated by means of the “SNO” experiment.

Finally, our combined t2m and lwin bias analyses suggests only a minor contribution of the bias in lwin to the overall bias in t2m, given their uncorrelated diurnal cycles and ranking with respect to humid vs dry conditions. This contribution will be assessed within the ATM experiment.

REFERENCES

Brousseau, P., Seity, Y., Ricard, D., & Léger, J. (2016). Improvement of the forecast of convective activity from the AROME-France system. *Quarterly Journal of the Royal Meteorological Society*, *142*(699), 2231-2243.

Dombrowski-Etchevers, I., Vionnet, V., & Quéno, L., Pertinence des prévisions météorologiques à l'échelle kilométrique pour la modélisation du manteau neigeux en montagne. *La Météorologie, Rubrique: Prévision,* 2017.

Martin, E., & Lejeune, Y. (1998). Turbulent fluxes above the snow surface. *Annals of Glaciology*, *26*, 179-183.

Quéno L, Vionnet V., Dombrowski-Etchevers I., Lafaysse M., Dumont M. and Karbou F. : Snowpack modelling in the Pyrenees driven by kilometric resolution meteorological forecasts, The Cryosphere, 10, 1571-1589, doi:10.5194/tc-10-1571-2016, 2016

Vionnet, V., Brun, E., Morin, S., Boone, A., Faroux, S., Le Moigne, P., et al. (2012). The detailed snowpack scheme Crocus and its implementation in SURFEX v7. 2. *Geoscientific Model Development*, *5*, 773-791.

Vionnet V., Dombrowski-Etchevers I., Lafaysse M., Quéno L., Seity Y., and Bazile, E. : Numerical weather forecasts at kilometer scale in the French Alps : evaluation and applications for snowpack modelling, J. Hydrometeor., doi:10.1175/JHM-D-15-0241.1, 2016