About orographic drag options in SURFEX

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Introduction

Many options are available in surfex code concerning the orographic drag. In surfex 4, the orographic drag parameterisation was computed under Isba part of Surfex code. This drag was not fully compatible with CANOPY SBL scheme, and has been externalized from Isba in Surfex 5 : Since Surfex 5, the orographic drag calculations are performed outside isba, directly under coupling_surf_atmn.f90.

The goal of this paper is to gather different tests that have been performed using AROME or Meso-NH concerning orographic drag options in surfex4, surfex5 or surfex7. All the tests are performed with CANOPY scheme switched on.

1) Available options

3 calculations of orographic drag have been implemented into Surfex :

a) Z01D

In this formulation, the orographic drag is a fonction of the orographic roughness length Z0 (computed in the PGD step) which do not depend on the wind direction. An example of this Z0 field is given over the AROME domain on Figure 1. Values are between 1 and 60 meters over orography, with a maximum over the alps.

ZOREL.LLHV2
2010_11_15_Lun_11h07m44s
min=0 max=64.857773 moy=0.827322752058 ect=3.115
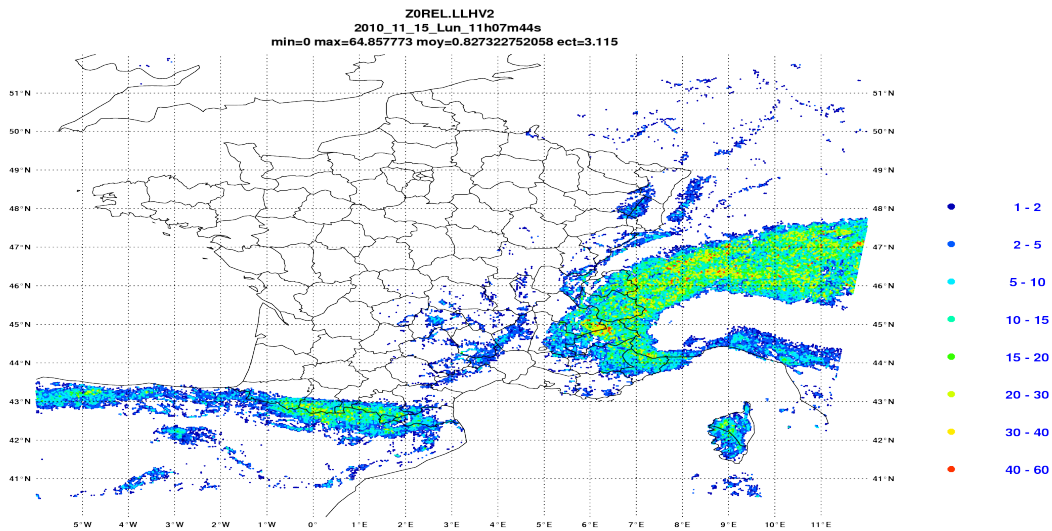
Figure1 : Orographic roughness length in AROME-France

The orographic drag formulation is the following :

$$drag_{Z01D} = \rho^2 . \left(\frac{0.4}{\ln\left(\frac{H}{Z_0}\right)} \right)^2 U \qquad (1)$$

with H the height of the atmospheric forcing level, U the wind strength, and Z0=MIN(Z0,H/2)

b) Z04D

This option is rather similar than the previous one, except the fact that Z0 is variable with the wind

direction.

c) BE04 (following paper published in QJRMS by Beljaars in 2004)
In this option, the orographic drag do not depend on Z0, but is related to the subgrid orographic standard deviation S_{st}. The wind speed is reduced by :

$$drag_{BE04} = 2.\alpha.\beta.C_{md}.C_{corr}.C_a.S_{st}^2.H^{-1.2}.\left(e^{\frac{-H}{1500}}\right)^{1.5} U \qquad (2)$$

with H the altitude, and S_{st} the subgrid orography standard deviation. Other variables are constants discribed in Beljaars (2004).

In surfex 4 (hereafter A), the 3 options are only available in Isba part. From surfex5 (hereafter B), Z01D and Z04D have been externalized from Isba. Indeed, in case CANOPY scheme is switched on, the atmospheric forcing level was 50cm (so, according to a), Z0 is limited to 0,25 m !) in surfex 4 (under isba), but 10m in AROME with surfex5 (under coupling_surf_atm, with Z0 limited to 5m). From surfex 7 (hereafter C), BE04 has also been externalized from isba.

In the following tests in surfex A, B or C, some tuning coefficients has been added to equations (1) and (2) : For Z01D, Z0 is limited by H/XFRACZ0 (instead of H/2) and for BE04, the drag can be multiplied by XCOEFBE. These 2 parameters (XFRACZ0 and XCOEFBE) are available by namelist in surfex7.1.

We will call the different experimental tests by X_YYYY(_Z) with X the surfex version used (A, B or C), YYYY the orographic parameterisation (Z01D or BE04) and in option, Z the value of the tuning parameters XFRACZ0 or XCOEFBE when they have been used. Note that for all tests, CANOPY scheme is switched on for Isba.

2) Xynthia case (27-02-2010)

On this severe storm case over the Pyrenees (Figure2), we compare 10m winds and gusts from different surfex options (Figures 3 and 4)
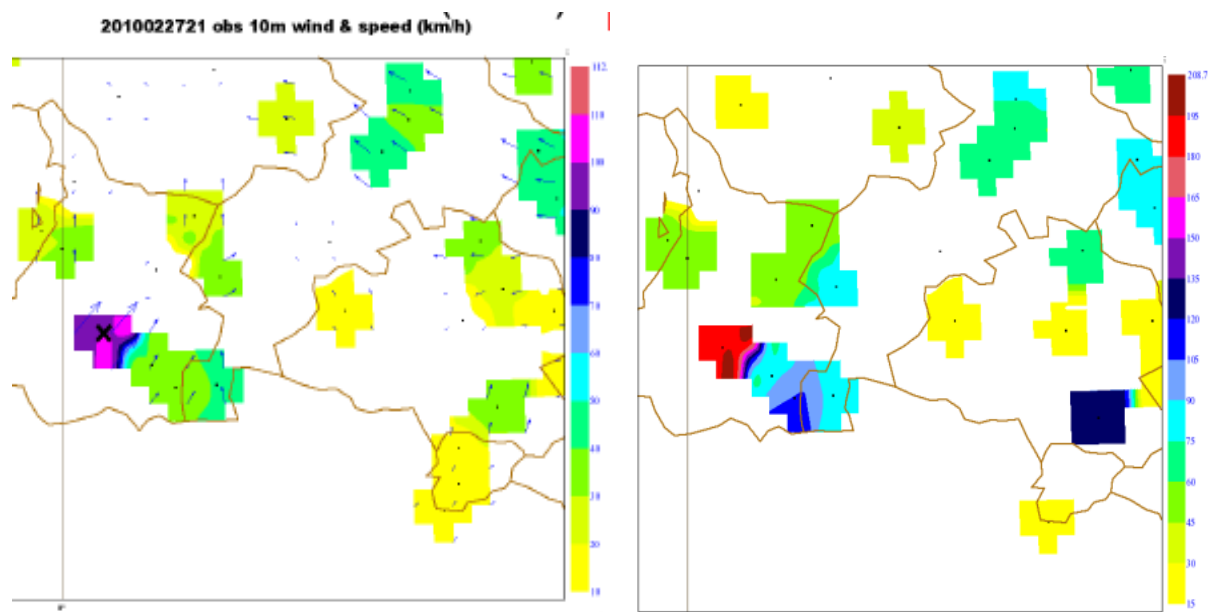
Figure 2 : Maximal observed 10m wind (left) and 10m gusts (right) at 21 TU
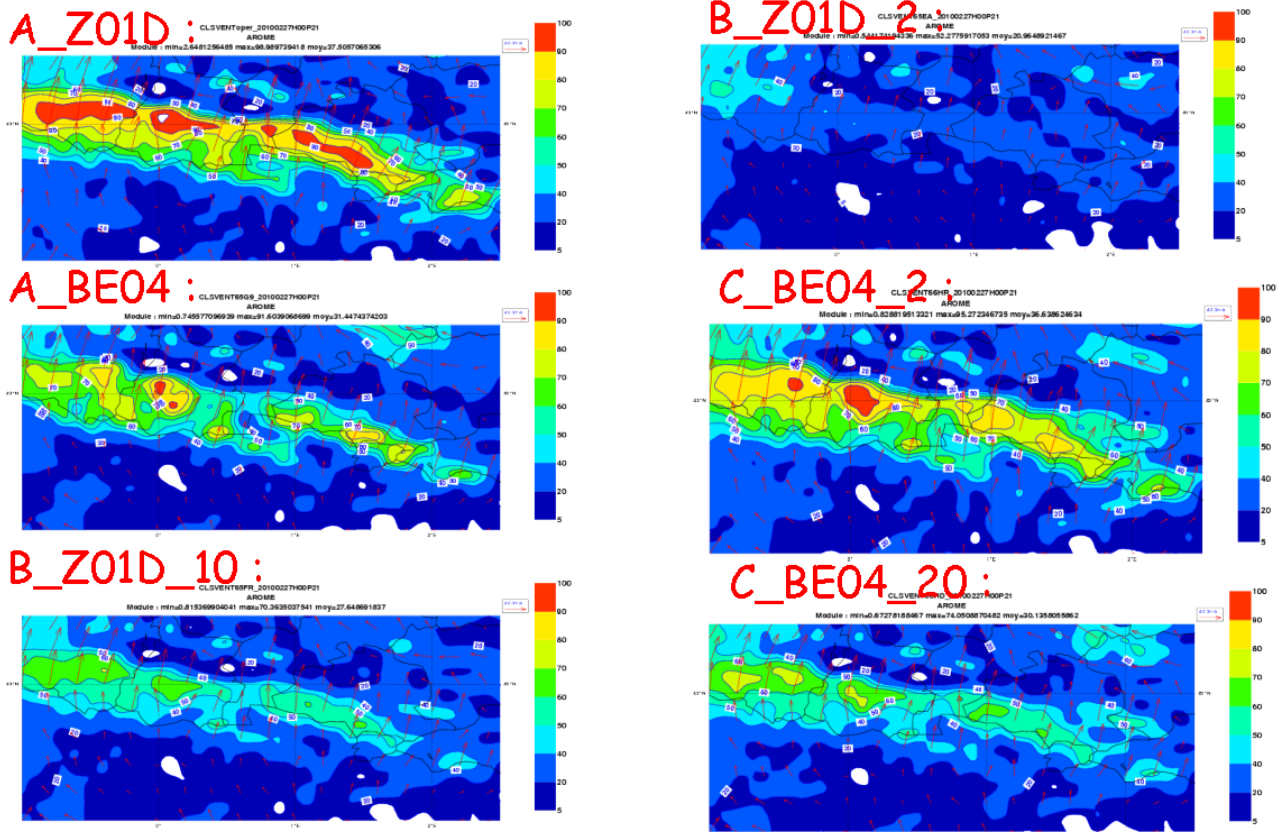
Figure 3 : AROME 10m wind forecasts over the pyrenees at 27 February 2010, 21TU (km/h)
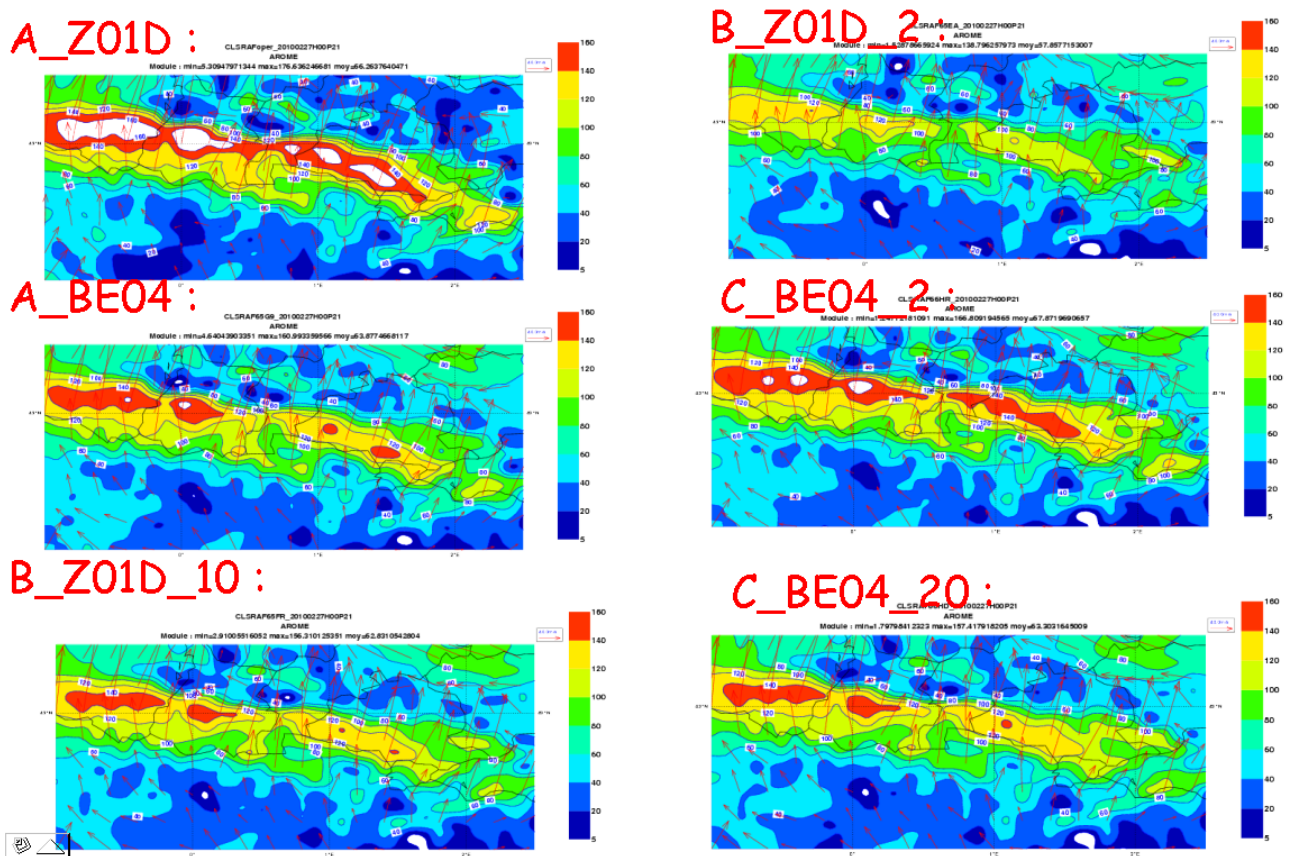

*Figure 4 : AROME forecasts 10m max wind gusts between 27 February 2010, 20-21 TU (km/h)*

At 21TU, observed winds are very strong over the Pyrenees. 110km/h has been reported over the Pic du Midi as 10m winds, and 209km/h as gusts.

A_Z01D forecast is correct, with a maximum value of 177km/h in gusts, and 102 km/h in 10m winds. In this experiment, as explained in 1) Z0 is limited to 0,25m.

Default version of surfex 5 (B_Z01D_2) clearly underestimates the winds. The orographic drag is too strong. When this drag is reduced (as in B_Z01D_10 in which Z0 is limited to 1m), results are improved, but still understimate the maximal wind gusts and winds (B_Z01D_10 : 156km/h and 71km/h, respectively). In the C version, the best result is abtained with BE04_2. MesoNH tests confirm this result.

3) monthly scores

In addition to the Xynthia case study, in order to evaluate the options on longer periods, we plot in this section automatic scores to Synop+RADOME stations for a one month period (from 15-10-2010 to 15-11-2010)
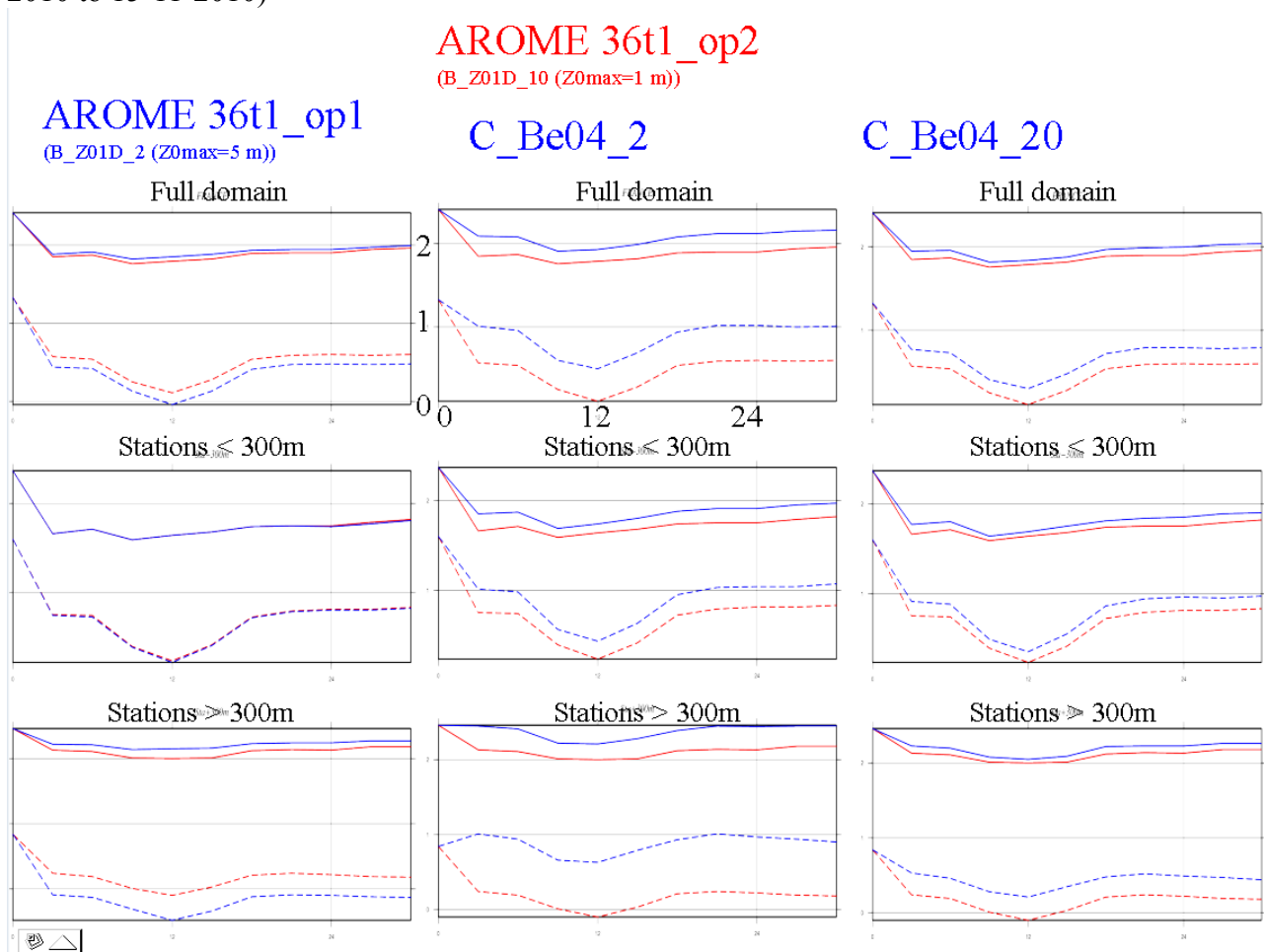
Figure 5 : Bias (dotted lines) and RMSE (solid lines) of 10m wind speed scores over AROME-Frangp domain. Top : all stations, Middle : stations < 300m, Bottom : stations > 300m.
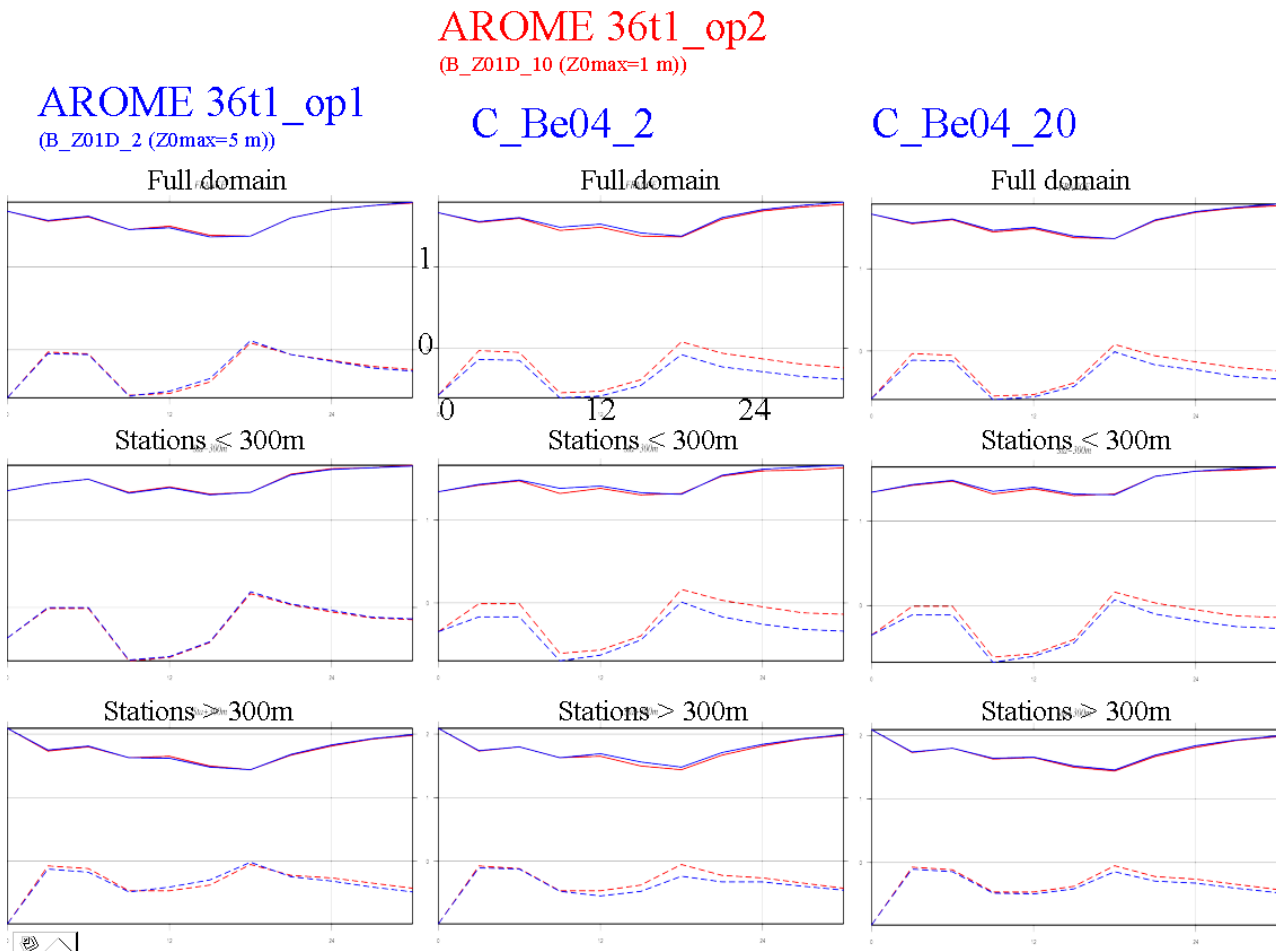
In the first column of Figure5, we can see that B_Z01D_2 (which was in operational AROME model in CY36t1_op1) underestimated the winds over orography (as for Xynthia case), and that B_Z01D_10 (current AROME oper in CY36t1_op2) strongly reduces this bias over orography, as the RMSE.

In the second column, C_BE04_2 which was rather correct on Xynthia exhibits strong positive bias and RMSE, which are reduced in the third column in C_BE04_20 but still are stronger than in B_Z01D_10. (C_BE04_2 is the default setting from Meso-NH Masdev49)
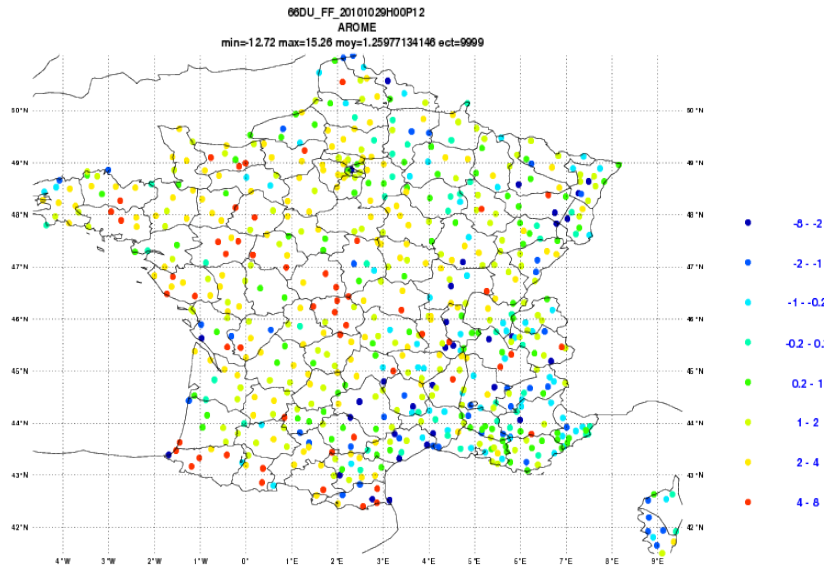
Figure 6 : 10m wind FF bias of C_BE04_2 at 2010-10-29 +12

In Figure 6, bias from C_BE04_2 has been reported at each station location on a particular day with strong winds. We can see that positive bias are not only located over orography. Consequently, we have no chance to fix them using XCOEFBE.

Figure 7 : Same as Figure 5 but for 2m temperature.

AROME 36t1_op2
(B_Z01D_10 (Z0max=1 m))

AROME 36t1_op1
(B_Z01D_2 (Z0max=5 m))
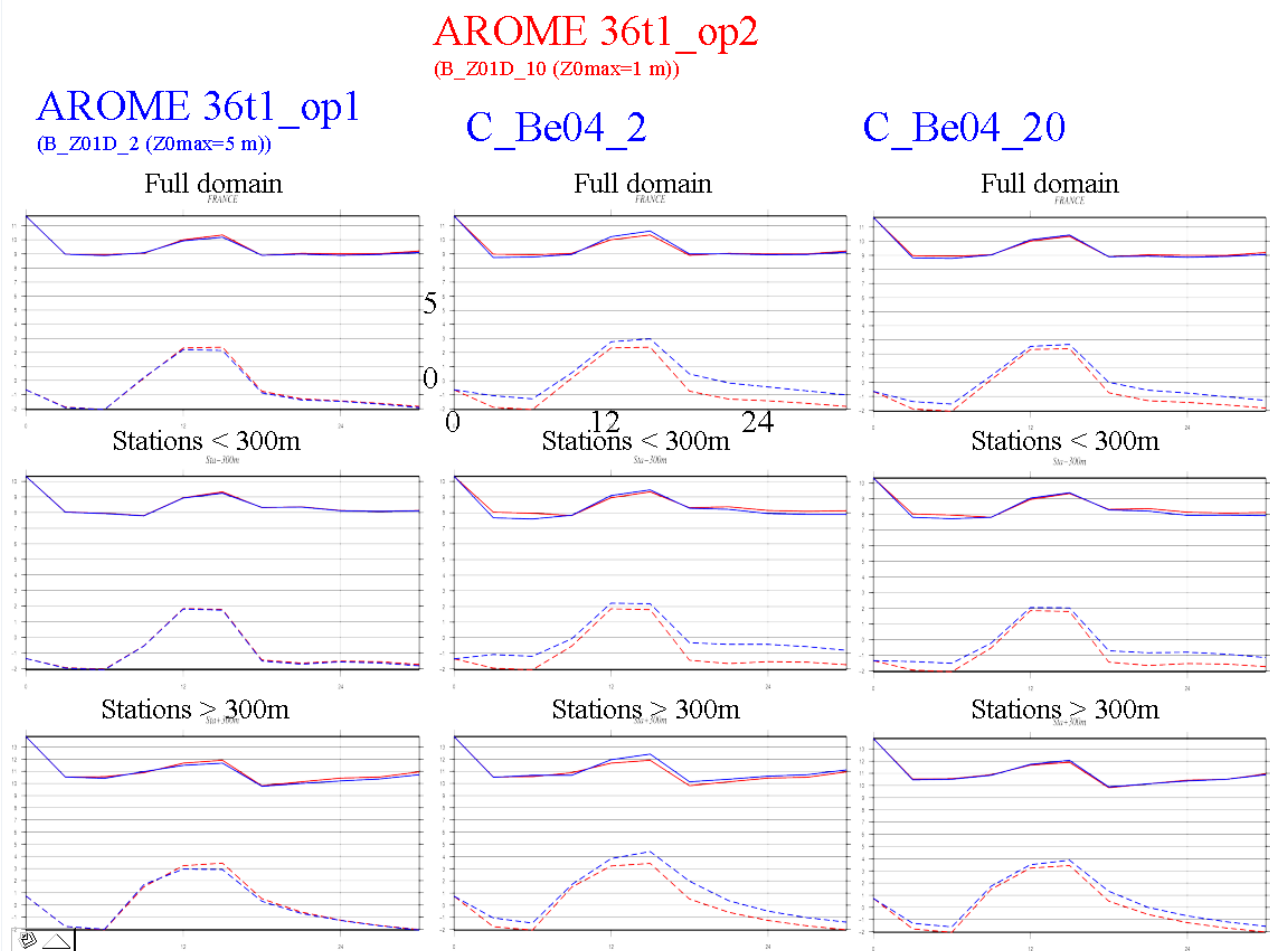
C_Be04_2

C_Be04_20

Figure 8 : Same as Figure 5 but for 2m relative humidity.

Concerning 2m temperature and relative humidity, BE04 has better scores than Z01D, especially for stations < 300m. C_BE04_20 is still better than C_BE04_2 for those 2 parameters.

4) **Complementary tests**

Hirlam people using AROME over Finland, Danemark or Norway has had same kind of problems when switching from CY36T1 (surfex4) to CY37T1 (Surfexv6+). As they had a lot of forests over their domain, as a complement of orographic drag, they activated LCANOPY_DRAG option to take into account tree drag in canopy. This reduces the wind speeds. After introducing a tuning coefficient in this LCANOPY_DRAG option, they seem to be satisfied by their scores.
Results from Hirlam can be found at :
https://hirlam.org/portal/validation/37h1/36h14_37trunk_201001/ for January and
https://hirlam.org/portal/validation/37h1/36h14_37trunk_201108/ for August

We also tested this option (without their tuning coefficient) combined with C_BE04_2. If it improves the 10m winds, it deteriorates T2m and Hu2m scores during night as shown in Figure 9.
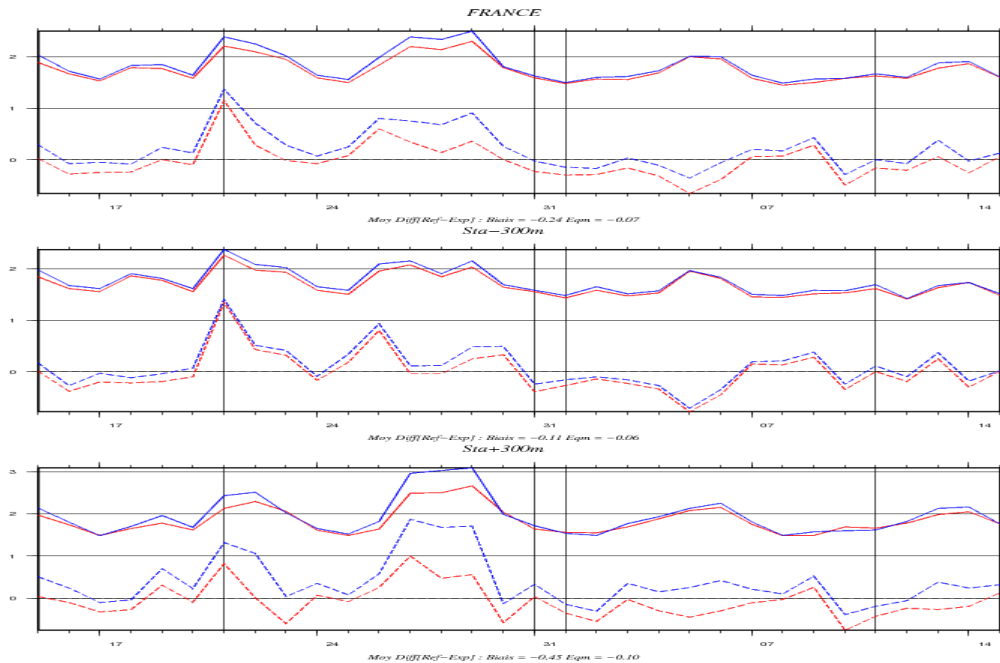
T2m   V10m   Hu2m
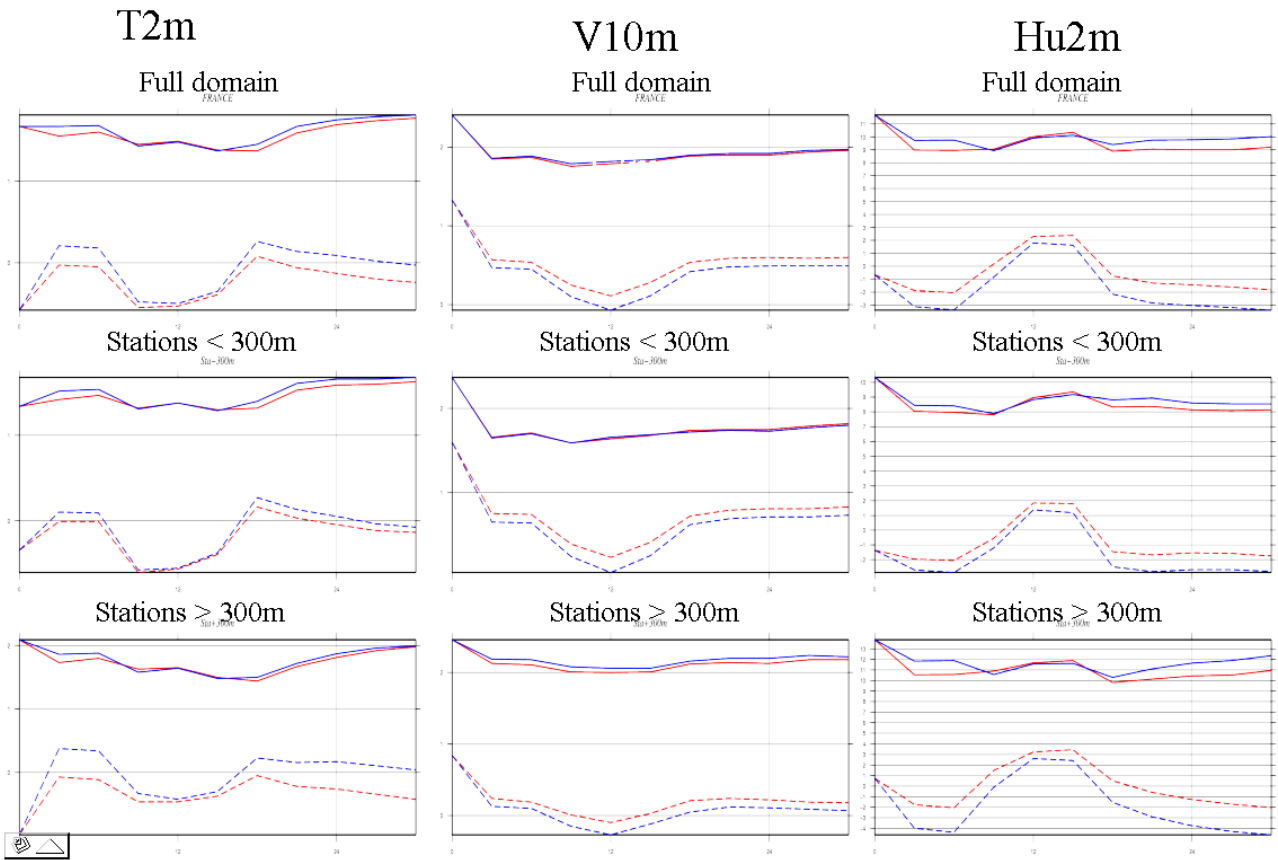
Figure 9 : Evaluation of LCANOPY_DRAG option in AROME

Looking at time evolution of this scores (Figure 10), 21, 22, 27, 28 and 29 October mainly contributes to the errors over orography. Those days were caracterised by anticyclonic conditions, with strong radiative cooling during nights.

Figure 10 : Evaluation of +03TU T2m bias and rmse from 15-10-2010 to 15-11-2010 (LCANOPY_DRAG in blue, B_Z01D_10 in red)

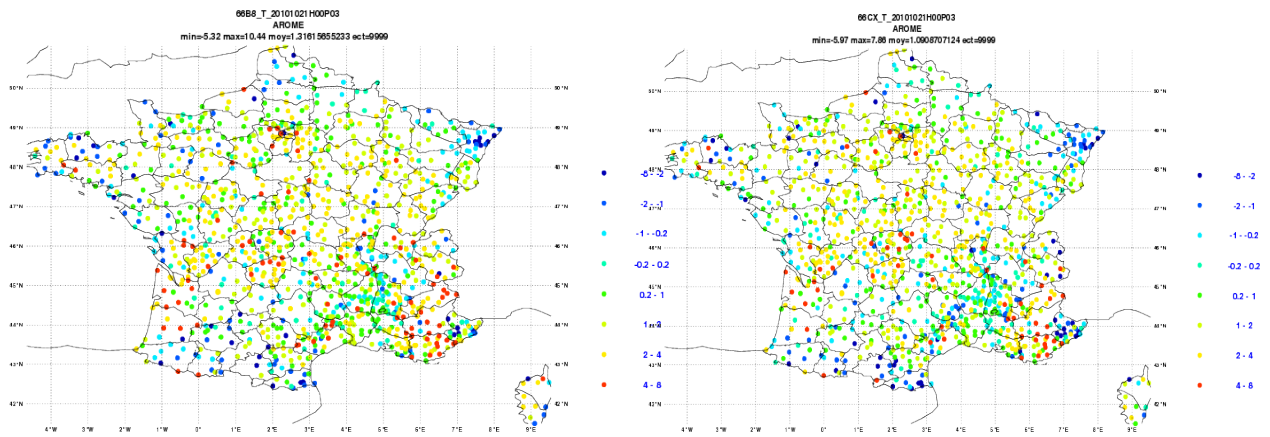The errors on temperature with LCANOPY_DRAG, not only increase over orography :

Figure 11 : 2m Temperature bias at +03 21-10-2010 (right : B_Z01D_10, left : C_BE04_2+LCANOPY_DRAG)

By chosing a smaller vegetation drag coefficient (ZCDRAG in isba_canopy.F90), with 0.075 instead of default values of 0.15 (Hirlam tests were done with 0.1), the results are improved :

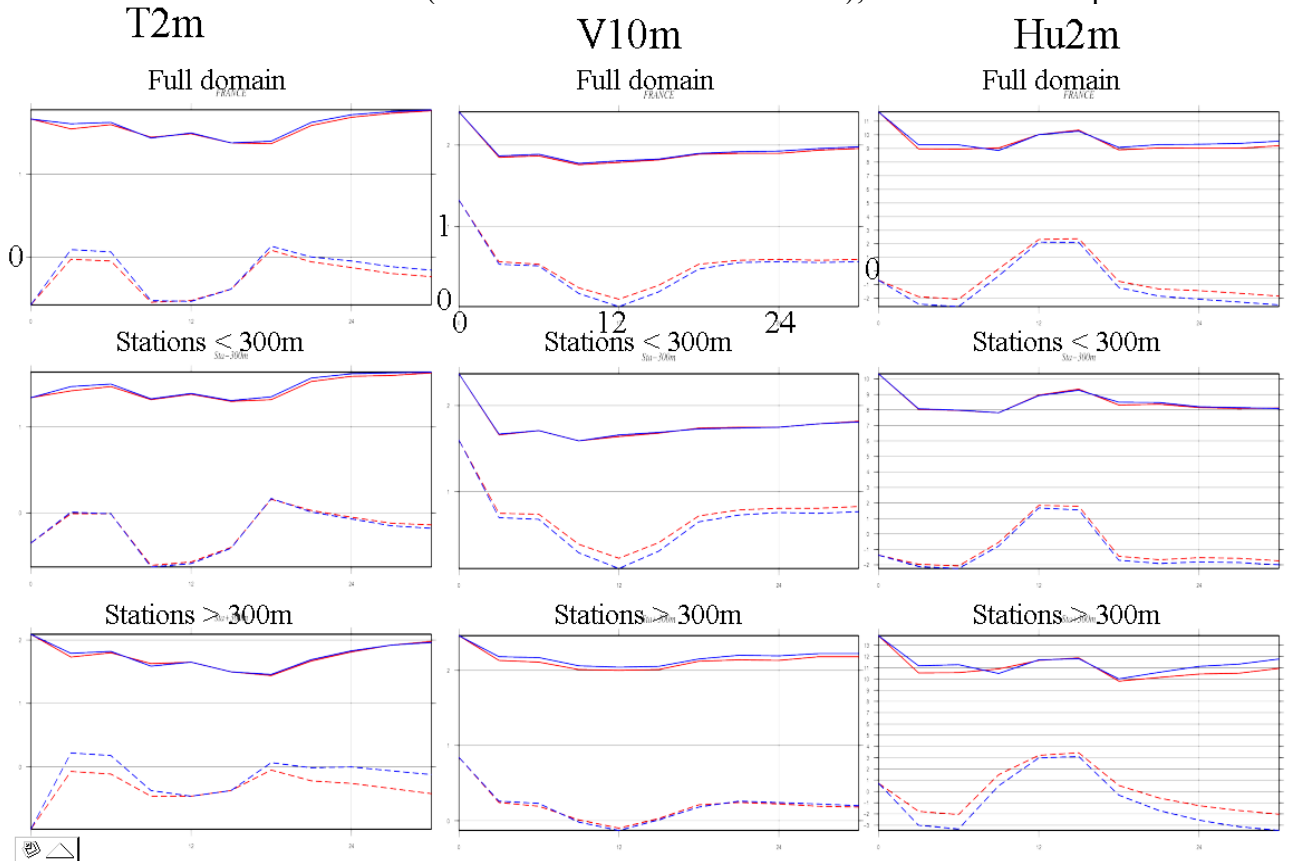

Figure 9 : Same as Figure 9, but with reduced vegetation drag coefficient *(=0,075 instead of 0,15)*

With this setting, scores are better than B_Z01D_10 for 10m wind and 2m temperature, and slightly deteriorated for 2m Hu.

5) <u>Conclusions and perspectives</u>

Since surfex5, the orographic drag has been externalized from isba. It is the only possible option in case CANOPY SBL scheme is switch on. Different settings of the orographic drag have been tested in AROME and in MesoNH. Compared to the surfex4 Z01D option in ISBA, the one used in AROME deteriorates the 10m wind speeds for Xynthia case (and also wind gusts, but in a lower quantity). On the other hand, the one used in Meso-NH Masdev49 (C_BE04_2), is correct on Xynthia case but deteriorates monthly scores of 10m winds. The addition of LCANOPY_DRAG with some tunings seem promising, even if a deeper evaluation is needed.

ANNEXE

Description of the namelist/cycles setings :

OPTION A : Orographic drag calculated only on Isba part. In surfex 4 (corresponding to CY35T2 in AROME or MASDEV48 in MesoNH) :
In this case, the orographic drag is done on the vegetation part (isba).
Different options are available : Z01D, Z04D and Beljaars (BE04).
&NAM_ISBAn
  CROUGH = "Z01D" or "Z04D " or "BE04"
/
In the following, option A_Z01D and A_BE04 will correspond to the corresponding CROUGH namelist options. Note that in the A_Z01D case, if CANOPY SBL scheme is switched on, the maximum orographic roughness length is 0,25m (half of the lowest canopy level depth).

OPTION B : In surfex 5 (corresponding to CY36t1_op1)
&NAM_ISBAn
  CROUGH = "Z01D" or "Z04D " or "BE04"
/
options are no longer available in case you use CANOPY SBL scheme.
In that case, you have to use the following namelist
&NAM_ISBAn
  CROUGH = "NONE",
/
&NAM_SSOn CROUGH = "Z01D" OR "Z04D " /
In GMAP, from CY36T1_op2, a new namelist option has been added in NAM_SSOn, in order to limit the orographic drag by HREF/ XFRACZ0, with HREF, the altitude of the lowest atmosperic model (10m in AROME-oper)
By default, XFRACZ0=2 (it is the hardcoded value of surfex5 Z01D orographic drag).
B_Z01D_10 corresponds to &NAM_SSOn CROUGH = "Z01D", XFRACZ0=10.,/ In that case, maximum roughness length for orography is 1m.

OPTION C :
In surfex7.1 (corresponding to CY38T1 or MesoNH Masdev49), previous options remains, and "BE04" has been added in &NAM_SSOn CROUGH.
Note that the isba/phys/sso_beljaars04.f90 has also been modified in order to be consistant with the paper from Beljaars et al, 2004 (a few coefficients have been changed)
In order to tune BE04 option, a multiplicative coefficient has been added in the code to this orographic drag : XCOEFBE.
C_BE04_2 will correspond to an increase by a factor of 2 of the BE04 orographic drag in NAM_SSOn.