Evaluation of AROME and ALARO wind forecasts in the Alpine region

LACE stay report

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0. Introduction

The main purpose of the two weeks stay was the evaluation of wind and gust forecasts provided by ALARO and AROME over the Alpine Area with a special focus on two aspects:

a. The influence of roughness length Z0 on wind and gust forecasts
b. The evaluation of the available options for gust forecasts

Both parts can be seen as a continuation of efforts made by other LACE colleagues, namely for (a) Martina Tudor and Jure Cedilnik and for (b) Ivan Bastak Duran. According to the findings of Martina (Tudor 2016a and 2016b) the presentation of roughness length and other physiographic fields in the ISBA climate files generated for the atmospheric model using conf 923 is highly questionable (e.g. SURFZ0.FOIS.G) and she proposed to exchange or derive these fields by others generated in the SURFEX/PGD world. This was also raised in Cedilnik 2016 who performed first tests using a 5km ALARO version. In the following, the outcome of several test runs are described which were performed for a representative wind case in the Alpine region. A “Föhn” – Case (initial time 20161120 12 UTC) was chosen as it is a typical wind situation with strong southerly/south-westerly wind over the mountain ridges mixing partly also down into the valleys and basins.

The last part of the stay was finally dedicated to investigate a problem which was found when running certain ALARO NH setups ‘causing somehow weird patterns in some model fields (e.g. radiation, near surface temperature and humidity, etc.). Unfortunately these problems are less visible in the wind field so they stayed somehow hidden for quite some time during the tests (as main focus was put on wind and gust forecasts). Finally it turned out to be a namelist/setup problem when making use of the predictor/corrector scheme. Section 5 in this document shortly summarizes the problem.

1. Model Setup and data

The major part of the model runs were performed on a 600x432 grid covering Central Europe with a 2.5km horizontal resolution using 90 vertical levels. This domain actually corresponds to the operational domain used at ZAMG for AROME. All runs were performed using cy40t1bf05 plus most of the bugfixes available for bf07 export version, e.g. bug found for quadratic coupling. Initial and boundary conditions were derived from IFS-HRES model, i.e. no assimilation is involved.

Table 1 lists the most important model runs performed during the stay. The last column indicates which type of roughness length was used during production of initial and coupling files in conf 927. Three types of sources for roughness length were used: a default PGD version (named DEF_PGD here) for AROME (and SURFEX), the default 923 output (named DEF_923) and a modified 923 output using SURFEX output fields (named MOD_V3) for ALARO. Some more details can be found in section 3.

EXPERIMENT NAME	PHYSICS	resol. / levels	DESCRIPTION	Roughness length
aro	**AROME**	**2.5 / L90**	**AROME-Aut Setup**	**DEF_PGD**
aro_recd	**AROME**	**2.5 / L90**	**AROME-Aut using “recommended dynamics”**	**DEF_PGD**
alaA	**ALARO1vA**	**2.5 / L90**	**ALARO1vA export namel, hydrostatic**	**DEF_923**
alaA_recd	**ALARO1vA**	**2.5 / L90**	**ALARO1vA using “recommended dynamics”**	**DEF_923**
ala5A	**ALARO1vA**	**4.8 / L60**	**ALARO1vA export namelist. hydrostatic**	**DEF_923**
alaA_mZ0_v3	ALARO1vA	2.5 / L90	Same as alaA_recd, modified roughness length	MOD_V3
alaA_mZ0_v3_raftke	ALARO1vA	2.5 / L90	Same as alaA_recd, modified roughness length, LRAFTKE=T	MOD_V3
alaA_mZ0_v3_raftke025	ALARO1vA	2.5 / L90	Same as alaA_recd, modified roughness length, LRAFKE=T, modified exponent in gust comp.	MOD_V3
aro_recd_candrag	AROME	2.5 / L90	Same as aro_recd, but Canopy scheme activated + LCANOPY_DRAG=T.	DEF_PGD

Table 1: List of model runs including short description used to run the 20161120 12 UTC case; forecast length 36 hours

A comparison between AROME and ALARO at the current stage is for sure not 100% fair as 1) SURFEX is just used for AROME while “old” pure ISBA is used for ALARO and 2) AROME has been extensively tested for the target resolution of 2.5km which are used here – in contrast to ALARO – and 3) using ALARO1vB (which was not used here) has the potential to be a further improvement with respect to ALARO1vA. In order to make the 2.5 km model runs as comparable as possible or to reduce the comparison as much as possible to model physics, the dynamics setup was set more or less equal for AROME and ALARO for most of the model runs. In the description (Table 1) it is referred to “recommended dynamics”. The wording is used as the setup was chosen according to the recommendation that can be found in Smolikova (2016). But it has to be pointed out that a translation of the documents recommendations (made for cy38t1) had to be done to cy40t1, which means some of the options were already obsolete or had to be moved or slightly changed. So the resulting namelists used for “aro_recd” and “alaA_recd” still might contain problematic choices. But as it turned out, at least for AROME they seem to make not too much difference to the “aro” version, i.e. the one following more or less the current AROME-Aut operational setup.

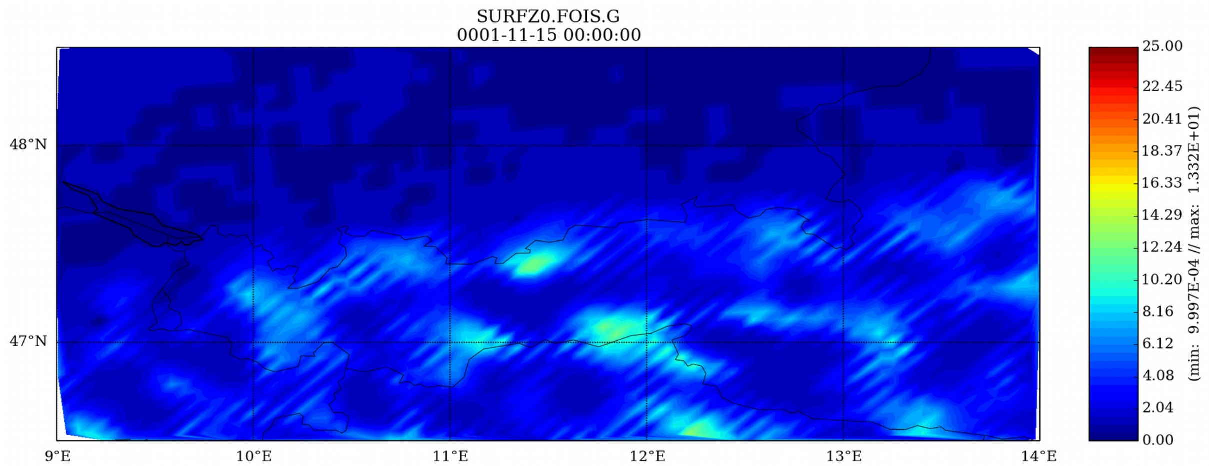
Automatic station data (TAWES) from ZAMG was finally used to verify the ALARO and AROME wind and gusts forecasts at station points. Station point forecasts where produced using epygram_1.0 software. For gust wind verification, the 10min TAWES data had to be aggregated to hourly max values.

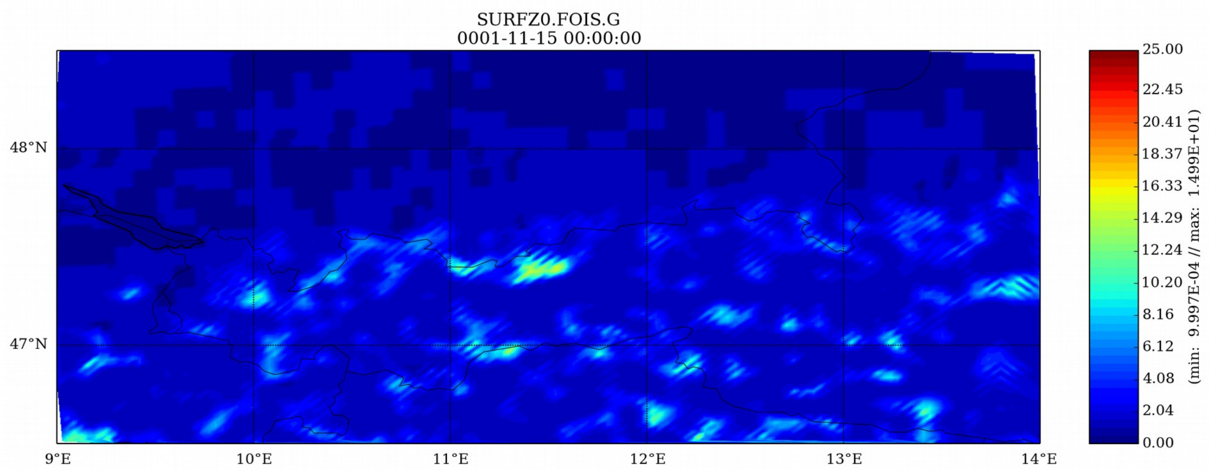
2. Roughness length in ISBA climate / SURFEX

Figures 2.1 and 2.2 show the roughness length Z0 (SURF.Z0.FOIS.G divided by g) as it is available from ISBA climate file for the atmospheric model for the model runs performed on 4.8km on 2.5km resolution, i.e. created with configuration 923. Figure 1.3 shows Z0 (SURFX.Z0REL) as it can be found in SURFEX output (switching on setting LPGD=.TRUE. and LCOEF=.TRUE. in EXSEG1.nam during 001). The geographical area shown here is the western, mountainous part of Austria and surroundings which is the area of interest for the 20161120 case study described in sections 3 and 4 ("Föhn" wind case). It is evident that the patterns seen in 2.1 and 2.2 (DEF_923 version in Table 1) look rather unphysical while the SURFEX/PGD version seems far more reasonable (DEF_PGD).
So it was decided to replace fields related to roughness length in the ISBA climate files using output from SURFEX/PGD:

- "SURFZ0.FOIS.G" replaced by "SFX.Z0REL*g",
- "SURFGZ0.THERM" replaced by "SFX.Z0REL*g/10".
- SURFZ0REL.FOIS.G replaced by SFX.Z0REL
- SURFZ0VEG.FOIS.G replaced by X001Z0VEG

Figure 2.4 finally shows the modified field SURFZ0.FOIS.G (divided by g) for the ALARO 2.5km runs (e.g. alaA_mZ0_v3). To replace/modify the fields, again epygram_1.0 software was used.





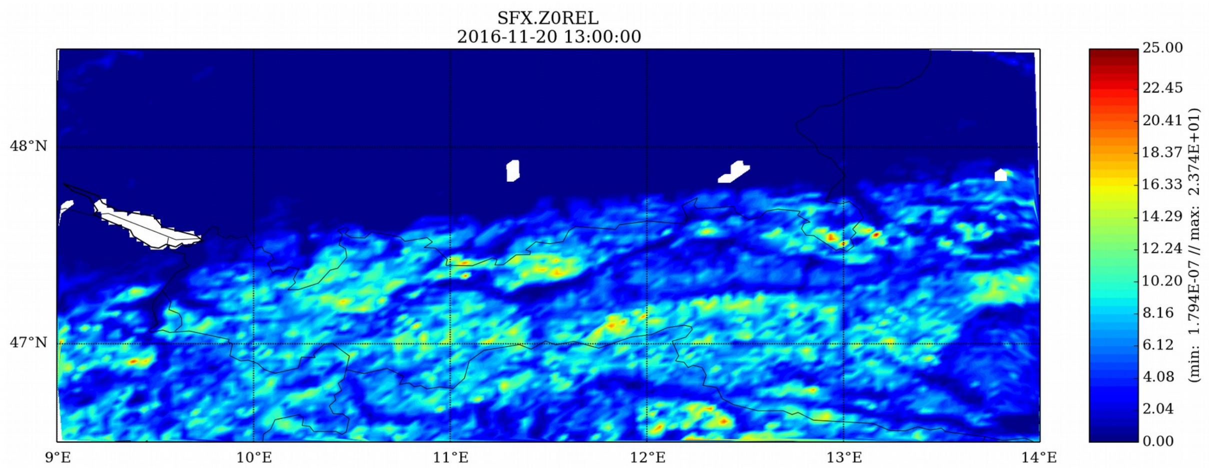


Figure 2.1 – 2.3: Roughness length Z0 [m] version "DEF_923" as seen in ISBA climate file after conf 923 in SURFZ0.FOIS.G (divided by g) in the 4.8km (top) and 2.5km (middle) case. Bottom: "DEF_PGD" roughness length (SFX.Z0REL) for 2.5km; zoom over western part of Austria (Vorarlberg, Tyrol and surroundings)

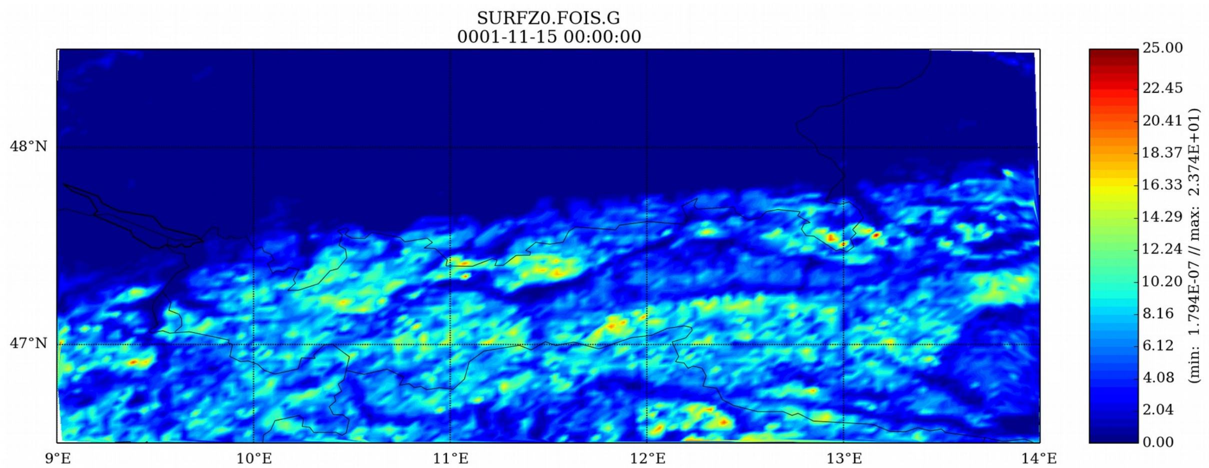


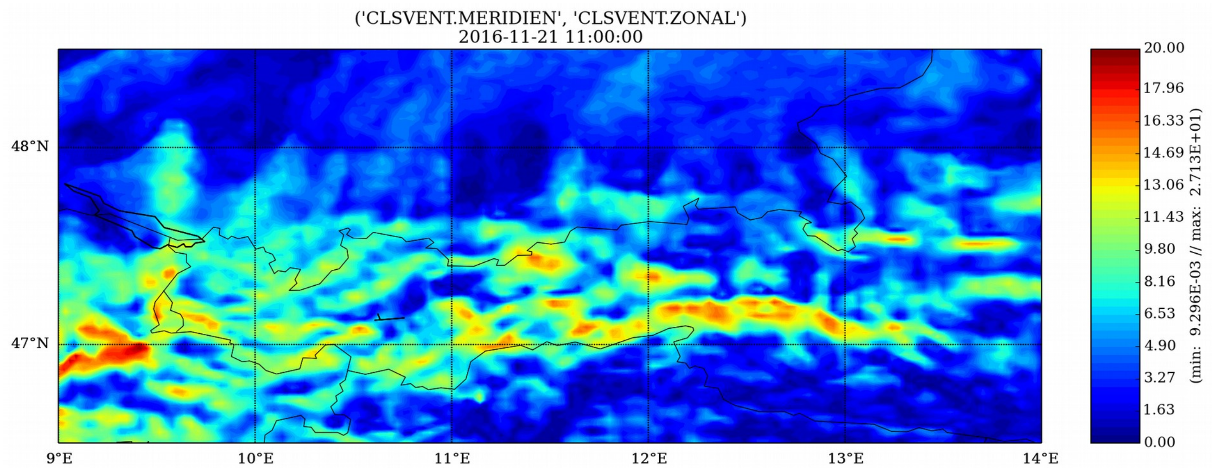
Figure 2.4: MOD_923 Roughness length Z0 [m] (divided by g) in 2.5km atmospheric ISBA clim file after replacement with SFX.ZOREL from SURFEX output

3. CASE STUDY 20161120 ("Föhn case")

3.1. "Default AROME and ALARO forecasts"

This case was chosen as it is a representative "Föhn" case in the Alpine region with significant southerly/south-westerly wind over the mountain tops and ridges and typically partly also in lower regions in valleys and basins. Comparing AROME (Figures 3.1 – 3.2) and ALARO forecasts (3.3. – 3.5) it can be seen that AROME 10m wind speed is significantly higher than the ones from ALARO. The difference between the default AROME run "aro" (Figure 3.1) and the one with recommended dynamics setup ("aro_recd", Figure 3.2) seems to be rather small. In general, compared to the ALARO 4.8km run (Figure 3.3), the ALARO 2.5km produces even lower near surface wind speed. The fact that ALARO 2.5km runs tend to produce such low near surface wind speed makes suspicious that something might not be optimal in the

2.5 km ALARO setup. But even when comparing the well tested ALARO 5km version (ala5A) there is a significant difference with respect to AROME.
Taking a look on the vertical cross section for “aro_recd” and “alaA_recd” in Figures 3.6 and 3.7 it gets clear that the differences are more visible for the near surface layers, i.e. wind and momentum are mixed down further to the valley grounds in the AROME case. How far wind is mixed down into the valley atmosphere is in general the most challenging aspect for models in these wind situations.
Further figures showing the AROME and ALARO wind forecasts in higher levels (roughly 100m and 200m above model orography) are shown in APPENDIX A. They confirm that the difference between ALARO and AROME starts to reduce with height.
We have to remember at this point, that ALARO runs shown in 3.3. – 3.5 and 3.7 use the rather“ unphysical” roughness length DEF_923. Results using a modified MOD_923 version are shown in the next section. Judging whether AROME or ALARO forecasts are closer to reality is rather easy for the areas / levels located around mountain tops and ridges. There, AROME forecasts seem to better represent the high observed wind speeds (while still underestimating them). In lower regions the situation gets far more complex as the station observations suffer from low spatial representativity in case of wind even more.
Using station data to verify the wind forecasts and compute Bias and MAE for all Austrian station as it is done for Figures 3.8, leads to the conclusion that AROME tends to overestimate 10m wind speed while ALARO (2.5km) tends to underestimate it. For ALARO 5km “ala5A” (4.8km) there is overall almost no Bias. But averaging all station (including high and low wind speeds) is just partly useful. Figure 3.9 and 3.10 indicate the Bias for each single station in Austria for the +23 hours forecasts. Figure 3.11 makes clear that the higher the observed wind speed, the higher (more negative) the Bias of AROME and ALARO forecasts get. For AROME activating LCANOPY_DRAG (computation of orographical drag in SURFEX) can help to reduce the positive Bias of AROME in this case (Fig. 3.14)



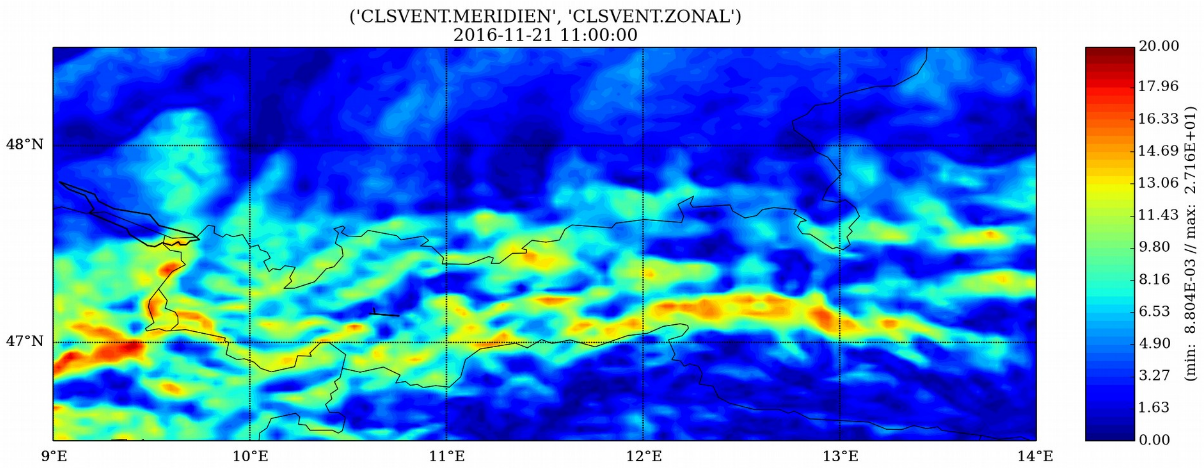
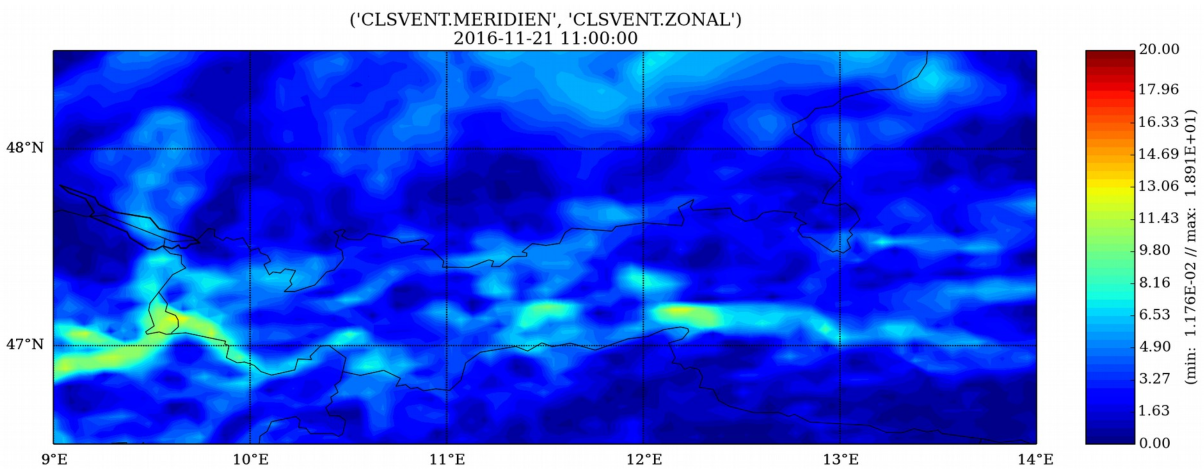
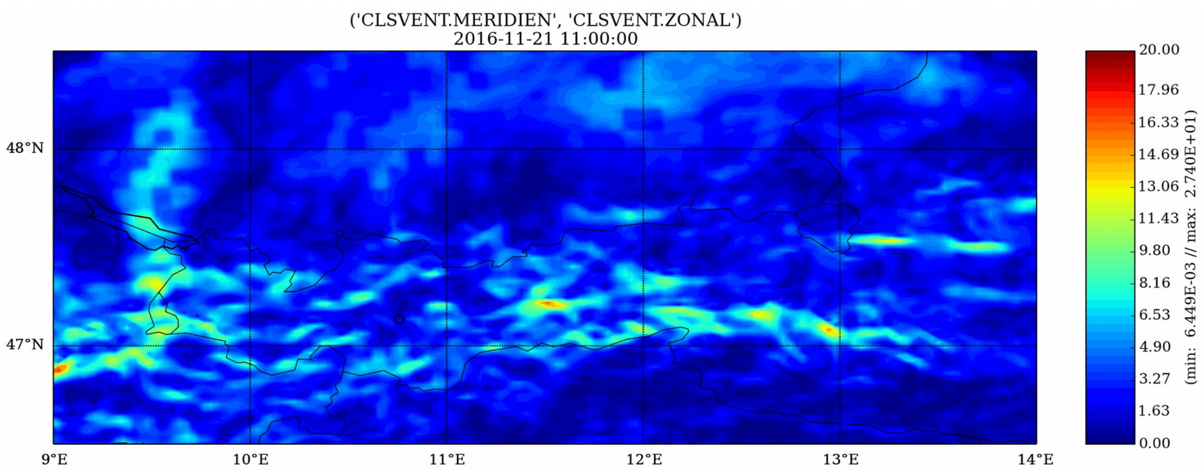


Figure 3.1 – 3.2.: 10m wind speed for AROME 2.5km model runs “aro” (top) and “aro_recd” (bottom) for 20161120 12 ZTC + 23h





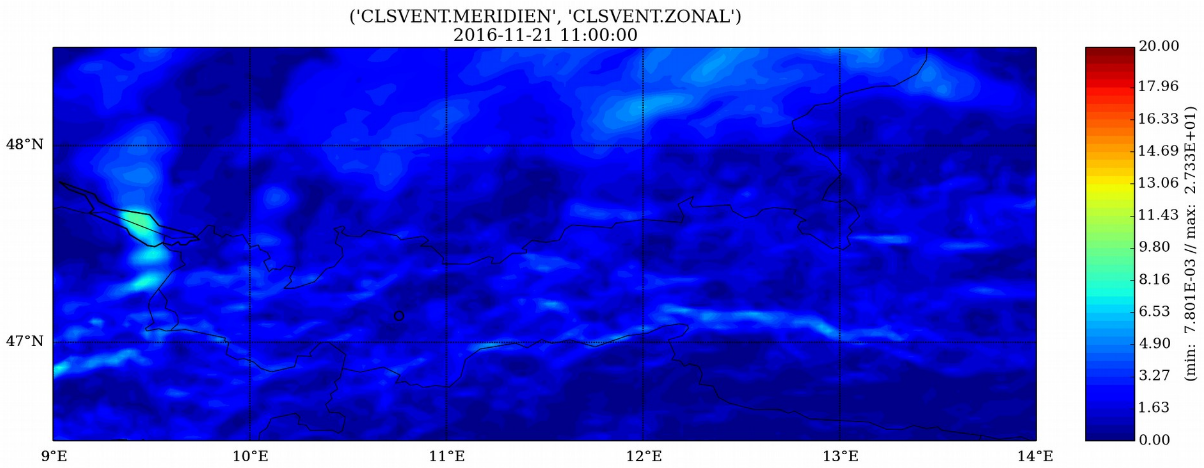


Figure 3.3. – 3.5.: 10m wind speed for ALARO 4.8km “ala5A” and ALARO 2.5km “alaA” (middle) and “alaA_recd” (bottom) test runs for 20161120 12 ZTC + 23h

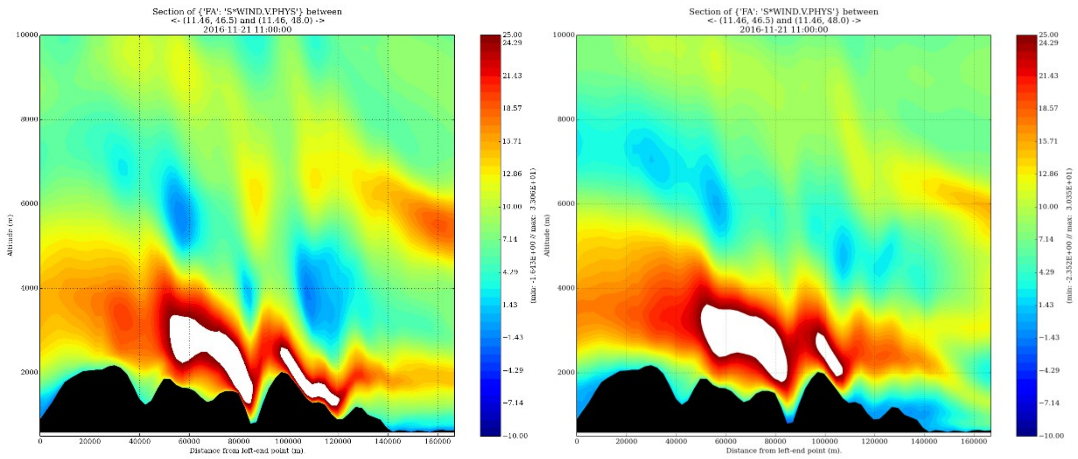


Figure 3.6. – 3.7.: Cross section with starting point 46.5/11.6 and ending point 48.0/11.6 for “aro_recd” (left) and “alaA_recd” (right) for 20161120 12 ZTC + 23h

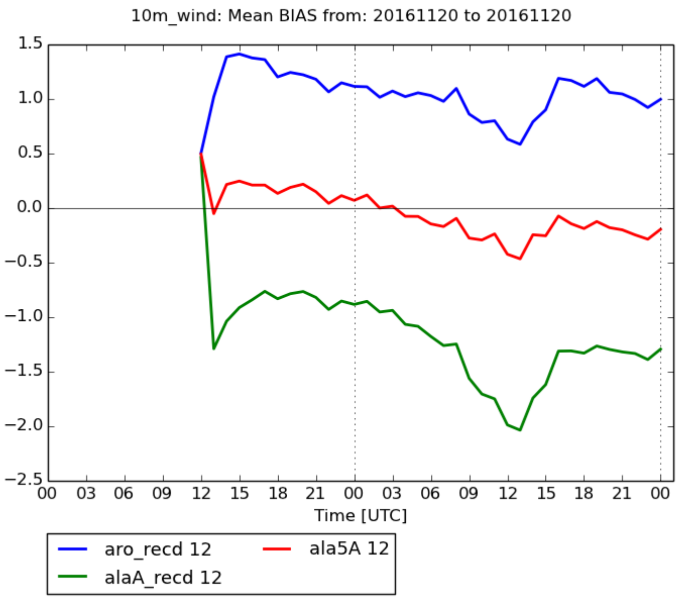
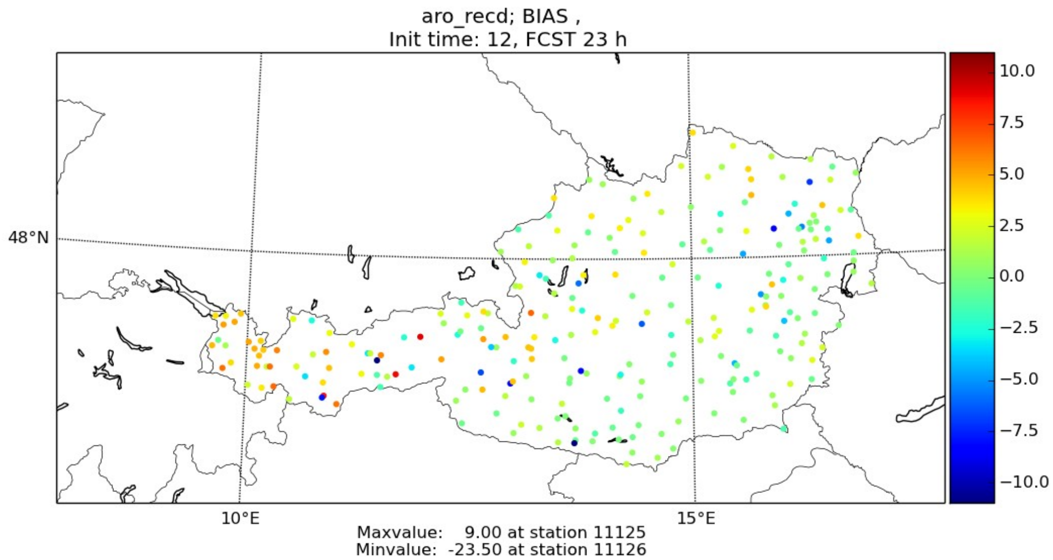


Figure 3.8.: 10m wind speed Bias based on all (roughly 250) automatic weather stations in Austria for the model run 20161120 12 UTC. Model shown: AROME "aro_recd", ALARO "alaA_recd" and "ala5A".



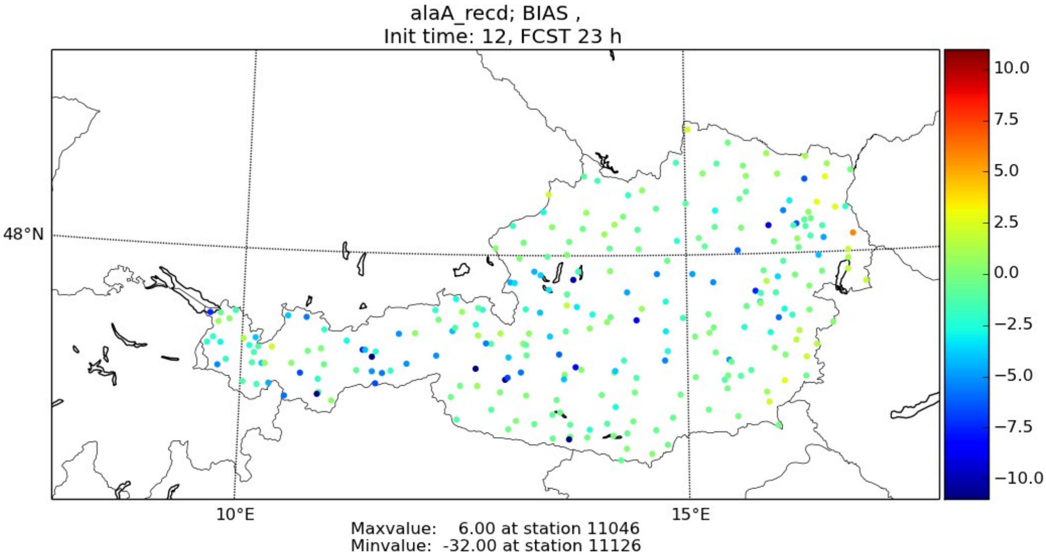


Figure 3.9 – 3.10.: Bias shown for each single station in for the model run 20161120 12 UTC for the runs “aro_recd” (top) and “alaA_recd” (bottom)

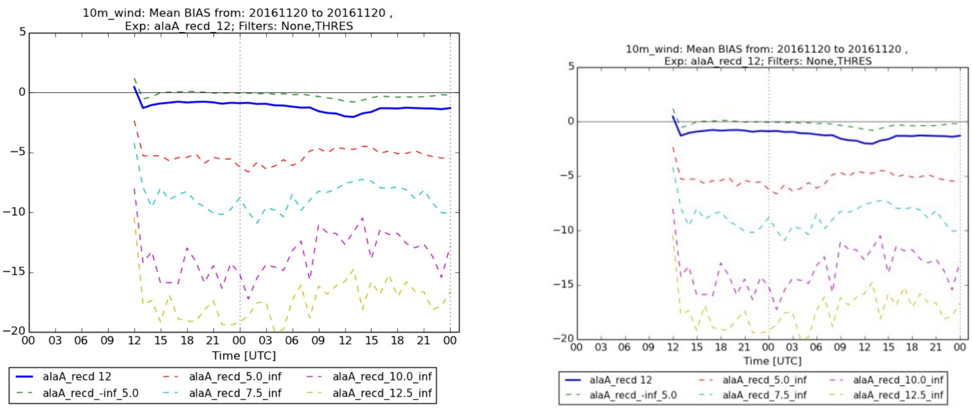


Figure 3.10 – 3.11.: 10m wind speed bias for different thresholds for AROME “aro_recd” (left) and “alaA_recd” (right) for the model run 20161120 12 UTC

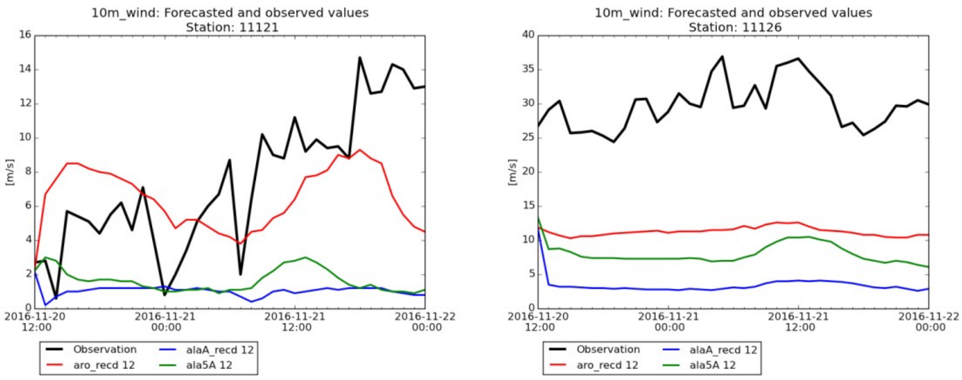


Figure 3.12 – 3.13.: 10m wind speed for Innsbruck (left) and mountain station Patscherkofel (right) AROME "aro_recd" and "alaA_recd" and observation (black) for the model run 20161120 12 UTC

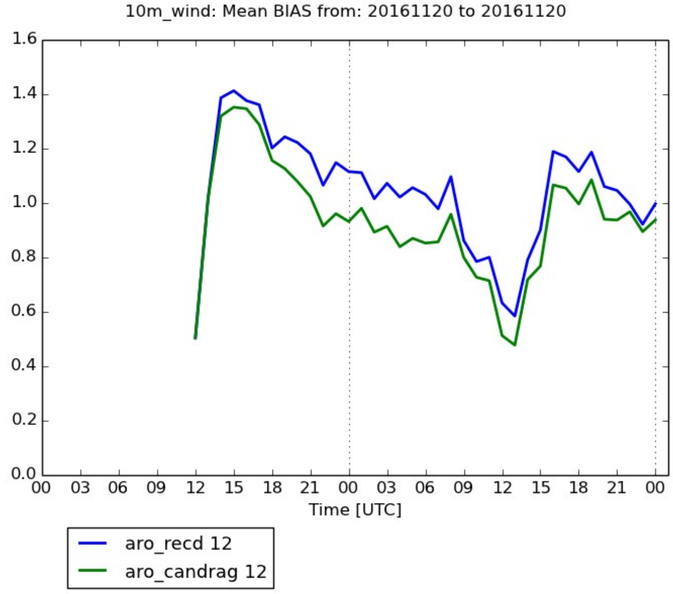


Figure 3.14.: 10m wind speed Bias based on all (roughly 250) automatic weather stations in Austria for the model run 20161120 12 UTC. Model shown: AROME "aro_recd" and AROME with activated LCANOPY_DRAG "aro_recd_candrag".

3.2. Modifying Roughness length

Up to now all ALARO runs presented have used the default conf 923 roughness length. The following results include the run "alaA_mZ0_v3" for which SURFEX/PDG type roughness length was used to replace the default ones in the ISBA climate files (see Figure 2.4). Compared to the run using default roughness length there are significant (3.15) differences. Some parts of the differences can be directly correllated to differences in terms of roughness length (3.16), others not. Comparing again the vertical cross sections (3.15. – 3.16) it can be seen that wind/momentum is now mixed down further to the valleys in the "alaA_mZ0_v3" case.

Taking a look on the verification (Figures 3.19 - 3.24) we can see that introducing the modified roughness length leads overall (seen on the base of all Austrian stations) to a reduction of the negative Bias (3.19), but also to an increase of MAE (3.20). Considering the other figures showing Bias for different (observed) thresholds (3.21 and 3.22) we would judge that we have overall a positive effect when using the modified roughness length 923_MOD.

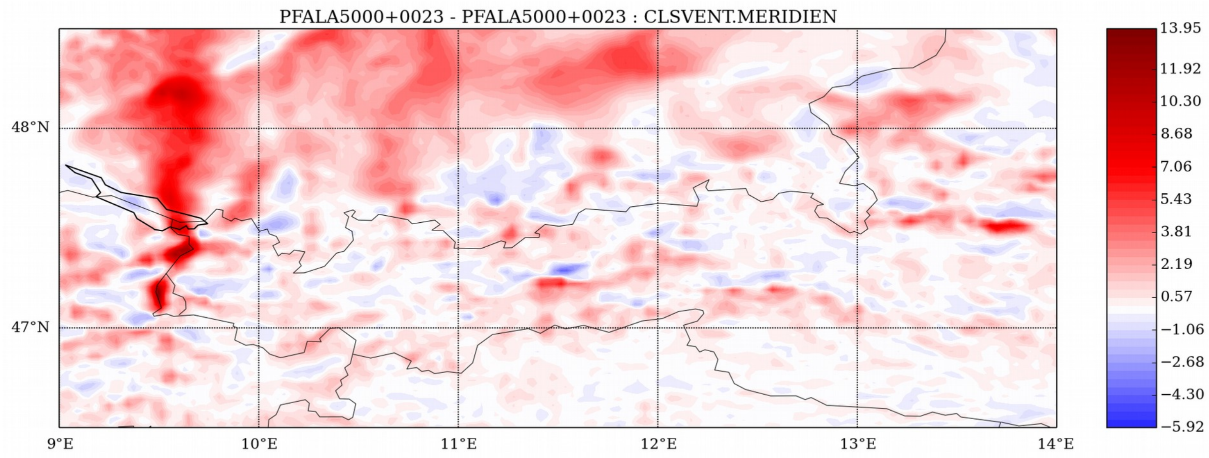


Figure 3.15: Difference for CLSVENT.ZONAL "alaA_mZ0_v3" – "alaA_recd" for 20161120 12 ZTC + 23h

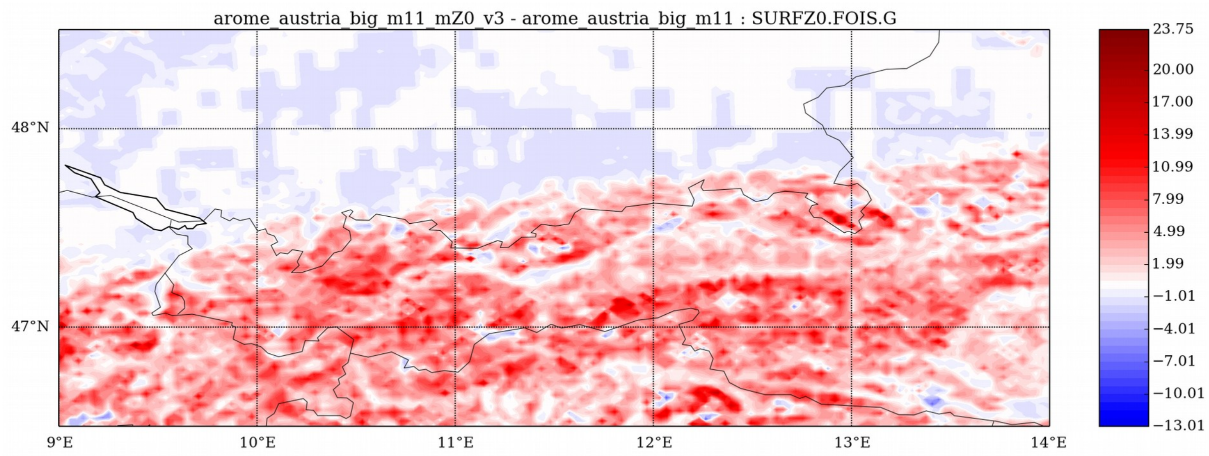


Figure 3.16: Difference for SURFZ0.FOIS.G (divided by g) "alaA_mZ0_v3" – "alaA_recd"

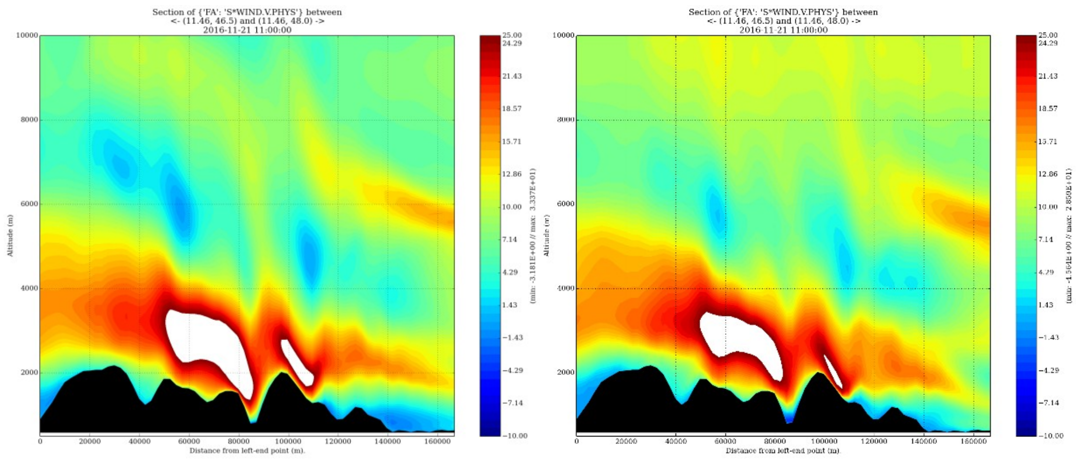


Figure 3.17 – 3.18.: Cross section with starting point 46.5/11.6 and ending point 48.0/11.6 for "ala4_mZ0_v3" (left) and "alaA_recd" (right) for 20161120 12 ZTC + 23h

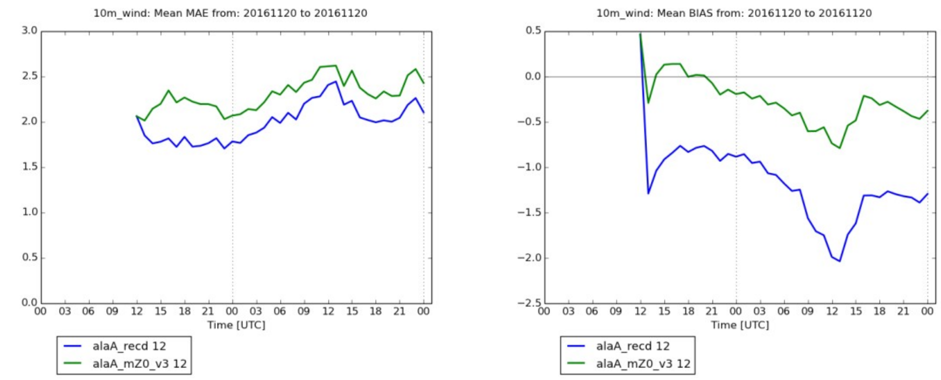


Figure 3.19 - 3.20.: Mean 10m wind Bias (left) and MAE (right) based on all (roughly 250) automatic weather stations in Austria for the model run 20161120 12 UTC for ALARO 2.5km runs "alaA_recd" and "alaA_mZ0_v3"

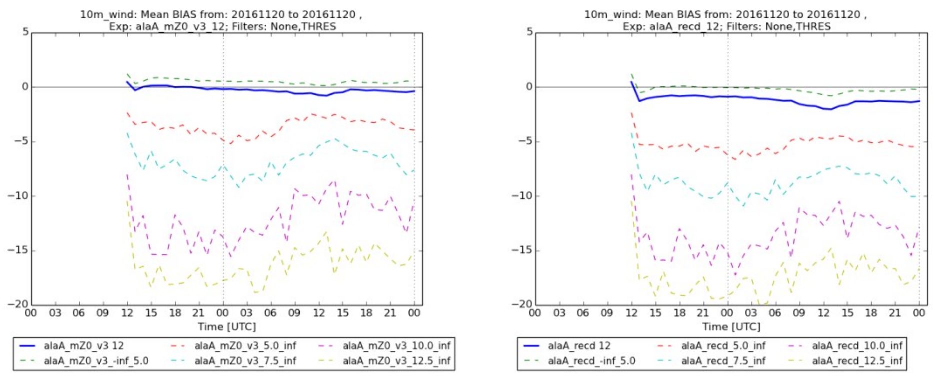


Figure 3.21 – 3.22.: 10m wind speed bias for different thresholds for ALARO 2.5km runs "alaA_mZ0_v3" (left) and "alaA_recd" (right) for the model run 20161120 12 UTC

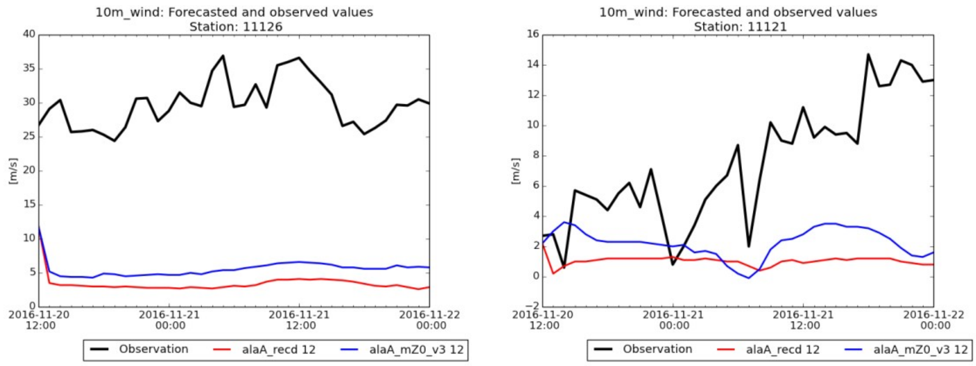


Figure 3.23 – 3.24.: 10m wind speed for Innsbruck (left) and mountain station Patscherkofel (right) AROME "aro_recd" and "alaA_recd" and observation (black) for the model run 20161120 12 UTC

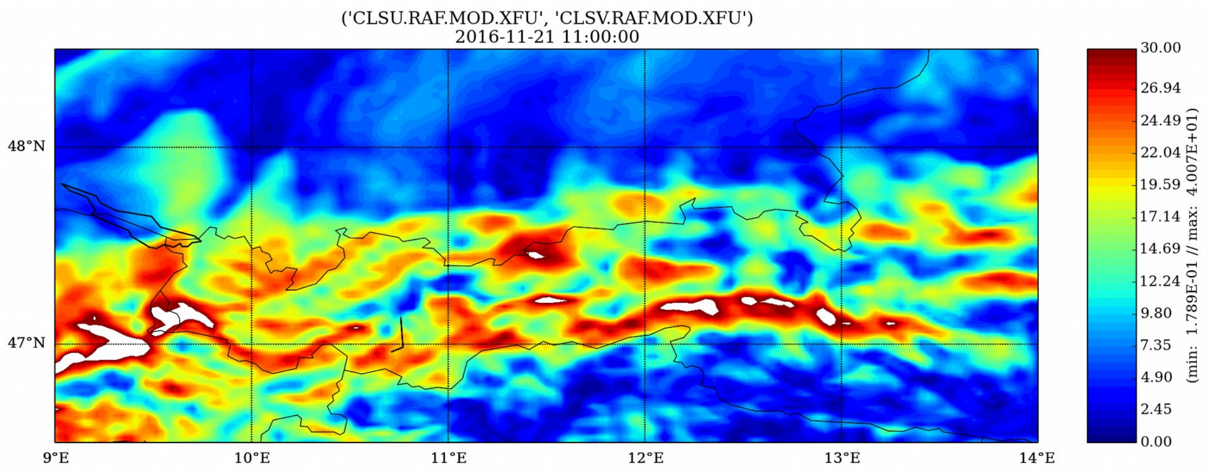
4. Gust forecasts

Currently there are basically two methods available in the ALARO/AROME code to compute the 10m wind gust speed:

I. LRAFTUR with tuning factor FACRAF
II. LRAFTKE with tuning factors FACRAF and HTKERAF

While the "old version" (I) is just available for ALARO version (II) is now available for AROME and ALARO. Both methods add a factor FACRAF*FACTOR to the mean wind on screening level height. The computation of FACTOR is different in the two versions: In (1) FACTOR = u* which is the so called friction velocity computed in routine achmt.F90 and in (2) FACTOR ~ sqrt(TKE) is based on available TKE up to a certain height (HTKERAF). In Bastak (2013) it is suggested to use a slightly modified relationship for the FACTOR, i.e. FACTOR ~(TKE)**0.25. So we end up with three version which were now tested for ALARO 2.5km runs. But we have to be aware that all version highly depend on the mean wind speed, so it is logical that AROME and ALARO differ in the same way (see 4.1. and 4.2) as we already saw in previous figures for the 10m wind, i.e. ALARO 2.5km gust wind is significantly lower than for AROME. From the verification plots (Fig. 4.3 – 4.5) we can see that the LRAFTUR version ("alaA_mZ0_v3") tends to produce little bit higher gusts speeds (less negative BIAS) than the LRAFTKE versions. The two LRAFTKE versions itself do not differ that much for this case.

In general, one can conclude that the version which is used to compute the gust wind has less importance as the major part of the differences already arises from the near surface wind field.



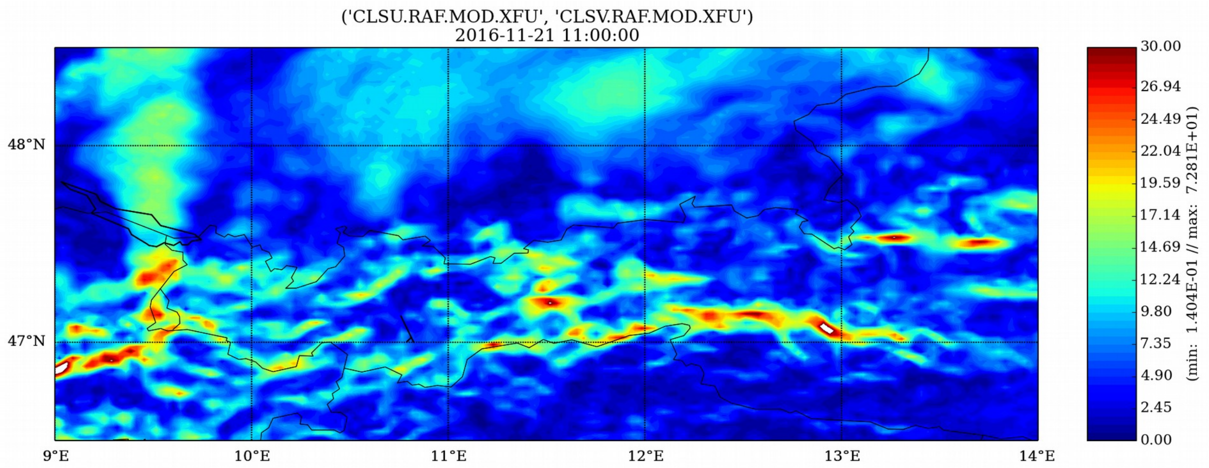


Figure 4.1 – 4.2.: 10m gust speed for ALARO 2.5 km run "alaA_mZ0_v3" (bottom) and AROME "aro_recd" for test runs for 20161120 12 ZTC + 23h

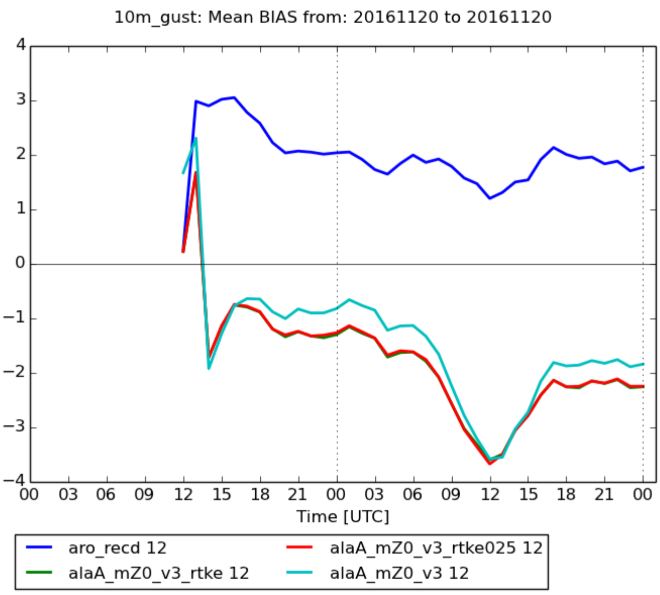


Figure 4.3.: Bias based on all Austrian weather stations (roughly 250) for different gust options in ALARO 2.5km and for AROME for the model run 20161120 12 UTC

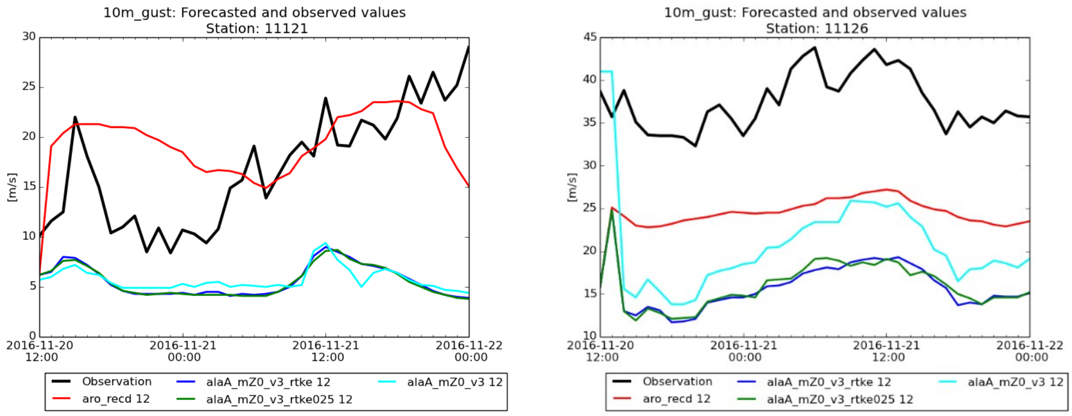
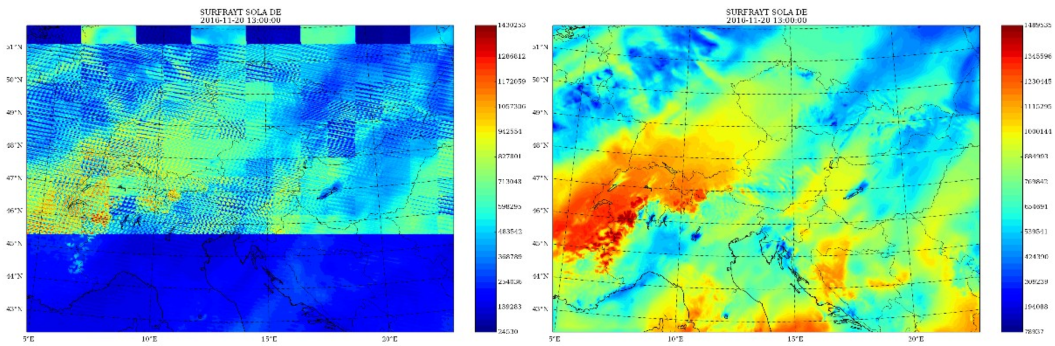


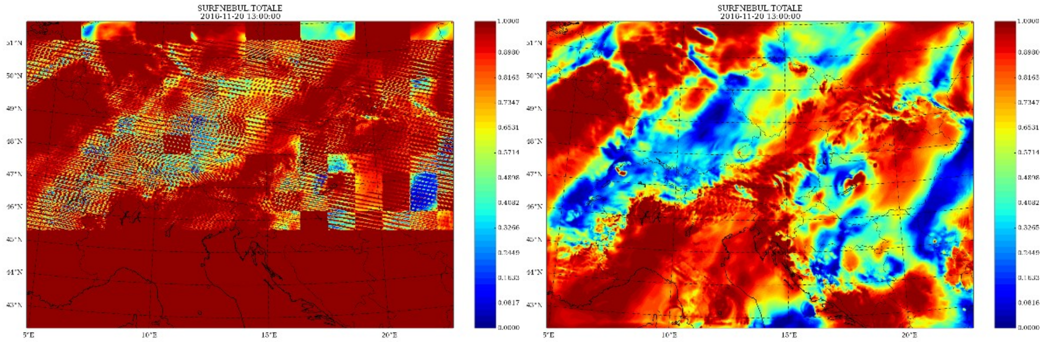
Figure 4.4 – 4.5.: 10m gust speed for Innsbruck (upper left) and mountain station Patscherkofel (upper right), Vienna (bottom left) and Airport Vienna (bottom right) for different ALARO 2.5km options and AROME for the run 20161120 12 UTC

5. Problems when using ALARO NH

During testing it turned out that the ALARO 2.5km versions running with “recommended physics” setup produce problematic patterns in certain output fields, e.g. radiation or cloudiness (Fig. 5.1. - 5.4). As these patterns are not really seen in the wind field, the problem stayed somehow hidden for some days during the stay. Performing various test runs while modifying certain parts in the dynamics setup the problem could be further localized to be connected to the setup of predictor/corrector scheme. And finally it turned out to be a pure namelist/setup problem: while in the case of AROME the keys %LPC in the NAMGFL have not to be set individually for the each advected GFL field it has to be set for certain fields when using ALARO otherwise we end up with the patterns seen in the figures below.

For future code version one might think of checking the PC setup in ALARO case, i.e. changing default values (to TRUE) for %LPC key for GFL fields when activating master LPC switches. This is obviously the case when AROME model is run (see also APPENDIX B)





6. Short Summary and Outlook

Several tests were performed using ALARO and AROME model on 2.5km resolution to evaluate the quality of wind and gust forecasts for a representative wind case in the Alpine region. The differences between AROME and ALARO near surface wind field in the Alpine region turned out to be rather big. The influence of roughness length was tested while replacing the default (and unphysical) roughness length fields in the ISBA climate file by more physical ones from SURFEX/PGD. The effect on the near surface wind field is visible, however it is difficult to judge from verification results whether the results are clearly better or not as the difference between stations/locations are rather big. Although the use of a physical meaningful roughness length field for ALARO seems logical, one might first overcome the fact that current physical schemes were tuned using the default and therefore questionable roughness length.

But not all differences (AROME / ALARO) can be of course assigned to roughness length and also surface (SURFEX). Part of it is for sure due to differences in PBL physics schemes. Although it is almost impossible to catch it from station point verification it seems to be evident that AROME near surface wind forecasts were little bit more realistic than comparable ALARO forecast for the selected foen case, as there was more realistic downward mixing of wind and momentum to the valleys observed in AROME. But it has to be stated, that the comparison done here is for sure not 100% fair as SURFEX should be also used for ALARO to better isolate the differences in the physics.

The fact that it was rather easy to end up improper setup of predictor/corrector setup in ALARO case might be topic for discussion to introduce more safety checks in to PC setup.

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Tudor, M., 2016a: Fields in ISBA clim files. Presentation at ALADIN Workshop 2016, Lisbon. Available at: http://www.umr-cnrm.fr/aladin/spip.php?article287

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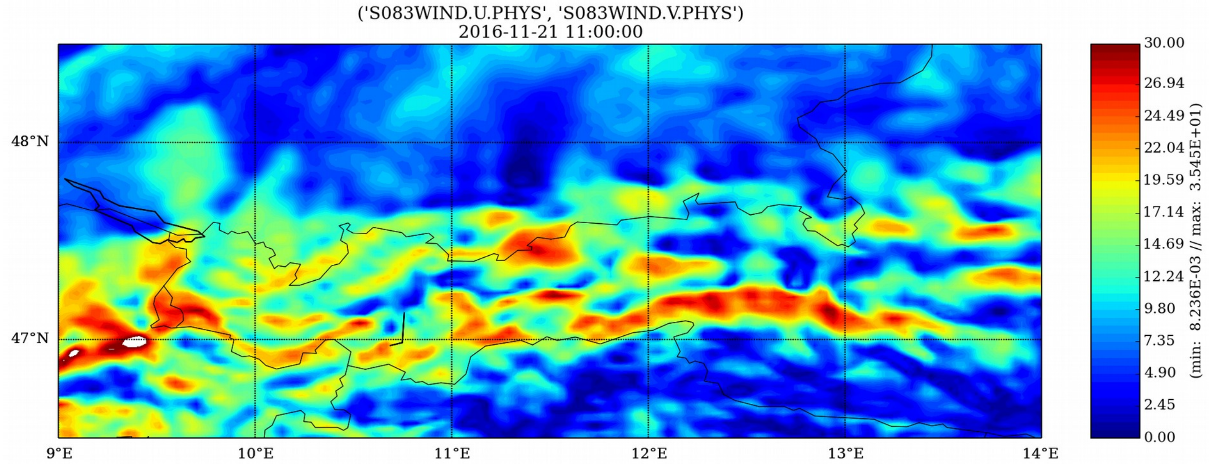
APPENDIX A



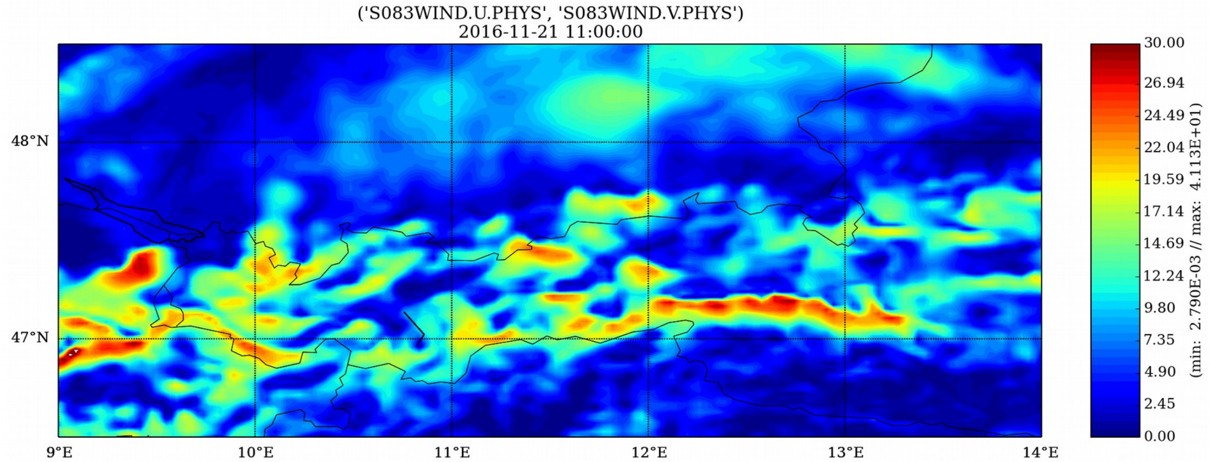
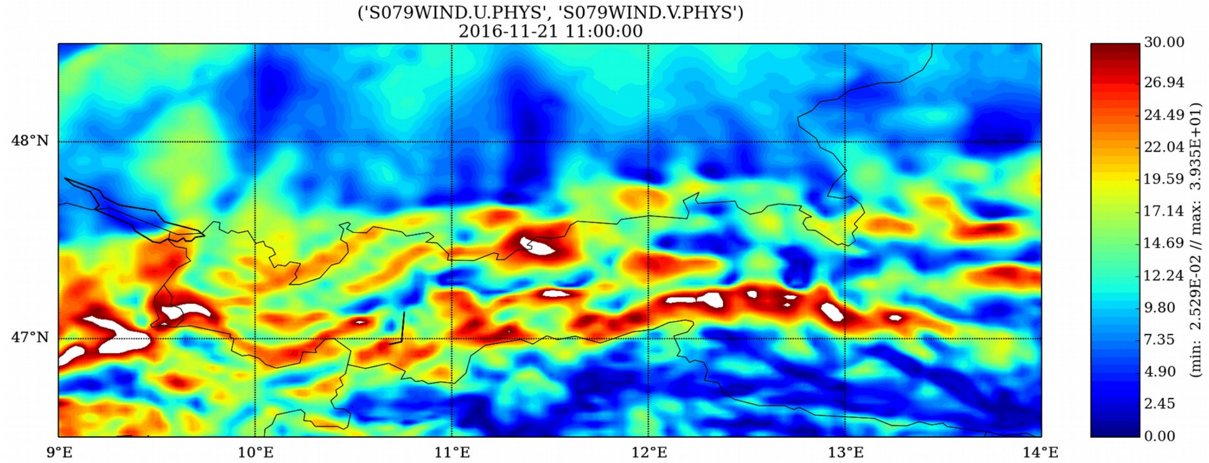


Figure A.1. – A.2: ~100m wind speed for AROME "aro_recd" (top) and ALARO "alaA_recd" (bottom) for 20161120 12 ZTC + 23h



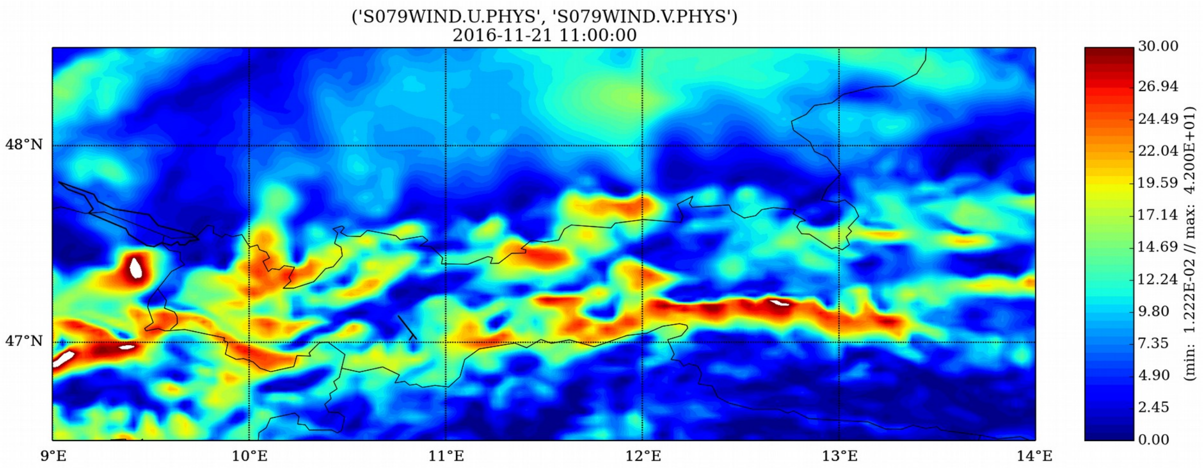


Figure A.3. – A.4: ~200m wind speed for AROME “aro_recd” (top) and ALARO “alaA_recd” (bottom) . for 20161120 12 ZTC + 23h

APPENDIX B

AROME case: GFL variables that can be found with activated LPC=T / LPC=F when using predictor/corrector scheme without setting extra %LPC=TRUE in NAMGFL namelist:

```
LPC TRUE:
  GFL COMPONENT DEFINED - NAME=RAD_SOLID_WATER  GRIBCODE=          247
  GFL COMPONENT DEFINED - NAME=RAD_LIQUID_WATER GRIBCODE=          246
  GFL COMPONENT DEFINED - NAME=SRC              GRIBCODE=          149
  GFL COMPONENT DEFINED - NAME=CLOUD_FRACTI     GRIBCODE=          248
  GFL COMPONENT DEFINED - NAME=TKE              GRIBCODE=          149
  GFL COMPONENT DEFINED - NAME=GRAUPEL          GRIBCODE=          149
  GFL COMPONENT DEFINED - NAME=RAIN             GRIBCODE=           75
  GFL COMPONENT DEFINED - NAME=SNOW             GRIBCODE=           76
  GFL COMPONENT DEFINED - NAME=ICE_CRYSTAL      GRIBCODE=          247
  GFL COMPONENT DEFINED - NAME=CLOUD_WATER      GRIBCODE=          246
  GFL COMPONENT DEFINED - NAME=HUMI.SPECIFI     GRIBCODE=          133

LPC FALSE:
  GFL COMPONENT DEFINED - NAME=EZDIAG03         GRIBCODE=          999
  GFL COMPONENT DEFINED - NAME=EZDIAG02         GRIBCODE=          999
  GFL COMPONENT DEFINED - NAME=EZDIAG01         GRIBCODE=          999
```

ALARO case: GFL variables that can be found with activated LPC=T / LPC=F when using predictor/corrector scheme without setting extra %LPC=TRUE in NAMGFL namelist:

```
LPC TRUE:
  GFL COMPONENT DEFINED - NAME=HUMI.SPECIFI     GRIBCODE=          133
  GFL COMPONENT DEFINED - NAME=ST_PREC_FLUX     GRIBCODE=            0
  GFL COMPONENT DEFINED - NAME=CV_PREC_FLUX     GRIBCODE=            0
  GFL COMPONENT DEFINED - NAME=TKE              GRIBCODE=          149
  GFL COMPONENT DEFINED - NAME=RAIN             GRIBCODE=           75
  GFL COMPONENT DEFINED - NAME=SNOW             GRIBCODE=           76
  GFL COMPONENT DEFINED - NAME=SOLID_WATER      GRIBCODE=          247
  GFL COMPONENT DEFINED - NAME=LIQUID_WATER     GRIBCODE=          246

LPC FALSE:
  GFL COMPONENT DEFINED - NAME=S SRC TERM TURB  GRIBCODE=           94
  GFL COMPONENT DEFINED - NAME=Q SRC TERM TURB  GRIBCODE=           93
```

```
GFL COMPONENT DEFINED - NAME=SHEAR TERM TURB  GRIBCODE=           92
GFL COMPONENT DEFINED - NAME=TOTAL_TUR_ENERGY GRIBCODE=           90
GFL COMPONENT DEFINED - NAME=PSHI_CONV_CLOUD  GRIBCODE=           79
GFL COMPONENT DEFINED - NAME=UD_ENTRAINMENT   GRIBCODE=           86
GFL COMPONENT DEFINED - NAME=DD_MESH_FRAC     GRIBCODE=           85
GFL COMPONENT DEFINED - NAME=DD_OMEGA         GRIBCODE=           84
GFL COMPONENT DEFINED - NAME=UD_MESH_FRAC     GRIBCODE=           82
GFL COMPONENT DEFINED - NAME=UD_OMEGA         GRIBCODE=           81
```