Evaluation of ALARO-5km near surface parameters over Austria with special emphasis on 2m temperature

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0. Content

1. Introduction

A 5km version of ALARO is running at ZAMG in a regular “pre-operational” environment since April 2009 (NH dynamics, 59 Levels). Recent verification results for precipitation show that according to the novel verification method SAL (Wernli et al. 2008) the 5km ALARO produces neutral to slightly better precipitation forecasts (over Alpine areas) than the current operational ALARO version at ZAMG running at 9.6km resolution (Wittmann et al. 2010). The present document describes the verification results for other near surface parameters (like 2m temperature, 2m relative humidity, etc) and gives a more detailed analyzes (and potential solution) for the 2m temperature problem in the 5km version of ALARO.

The verification package used at ZAMG to verify station point forecasts includes following near surface parameters:

- 2m temperature
- 2m relative humidity
- 10m wind speed
- 10m wind gusts
- Total cloudiness
- Mean sea level pressure
- 10m Wind direction

The verification is done for 152 stations in Austria, whereas the stations are assigned to different categories according to their station height: 0-500m, 500-1000m, 1000-1500m, > 1500m. The verification period is 20090601 – 20090831, just 00 UTC runs are used and forecast range is 48 hours.
In the following the results for the comparison of ALARO-5km (referenced as ALARO5 in the following) and the operational 9.6km ALARO version (OPER) at ZAMG are briefly discussed. In Section 2, the results for 2m temperature are discussed in more detail.

1.1. Mean sea level pressure

ALARO-5km clearly shows a better performance than the operational version. For this parameter the benefit of using higher resolution is clearly visible. Figure 1 shows the mean MAE, BIAS and RMSE for 60 stations located in an altitude from 500 – 1000m. The RMSE for ALARO5 shows similar values as the MAE of the operational version. The positive impact is also visible for the 0-500m stations, but as one may expect less clear. There was no verification computed for stations located higher than 1000m (observed pressure is reduced to higher pressure levels, this makes model verification little bit more difficult)

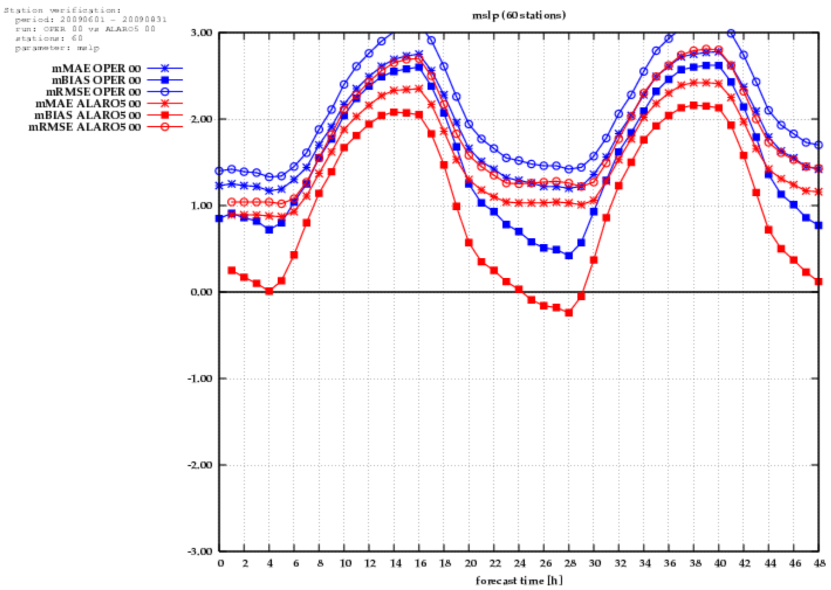


Figure 1: Mean MAE, BIAS and RMSE for MSLP for 60 stations located in elevations ranging from 500m – 1000m.

1.2. Wind speed (and direction)

For wind speed the situation is less clear. For stations below 1500m stations the scores for wind speed are slightly neutral to slightly worse for ALARO5. Figure shows the scores for 10m wind speed, again for stations in altitudes from 500 – 1000m. MAE, RMSE and BIAS are larger for ALARO5. The results are similar to the ones for stations in 0-500m and 1000-1500m. For stations located above 1500m the results for ALARO5 and OPER are very similar.

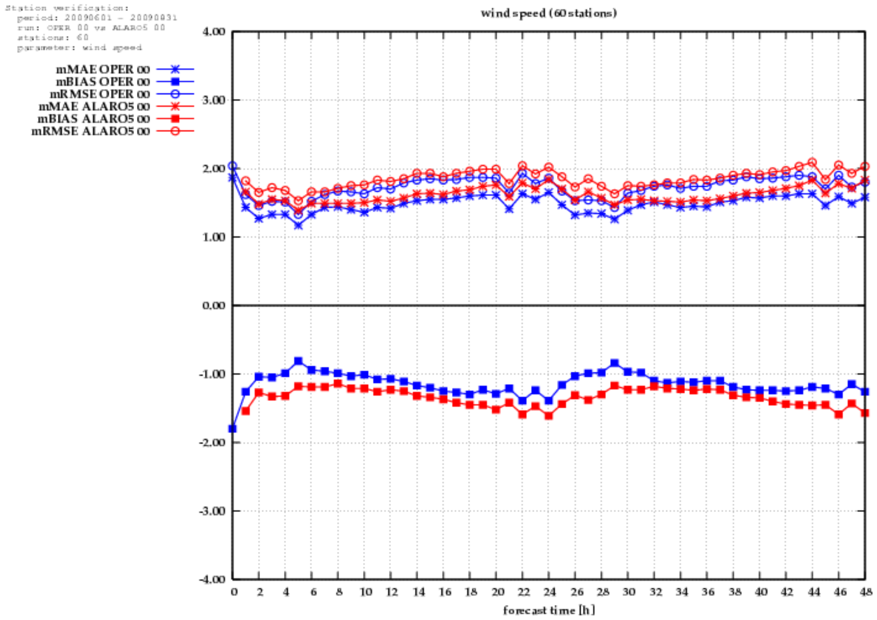


Figure 2: Mean MAE, BIAS and RMSE for wind speed for 60 stations located in elevations ranging from 500m – 1000m.

For wind direction it is not possible to draw conclusions, as the results to not really show whether ALARO5 or OPER perform better. The sign (ALARO5 better than OPER and vice versa) is changing from forecast step to forecast step. One may expect that the higher resolution ALARO5 creates more realistic wind fields in the mountainous regions due to the more realistic topography.

1.3. Relative humidity

For relative humidity the results clearly show a better performance of ALARO5. Figure 3 shows the results for stations located below 500m altitude. It can be seen that even in region, where in general the topography for OPER and ALARO5 is not that different, higher resolutions can bring benefit (Figure 3). For stations in higher altitudes the benefit gets more and more visible (Figure 4). The quality of near surface relative humidity forecasts stays questionable anyway (large diurnal cycle with largest errors during the day).

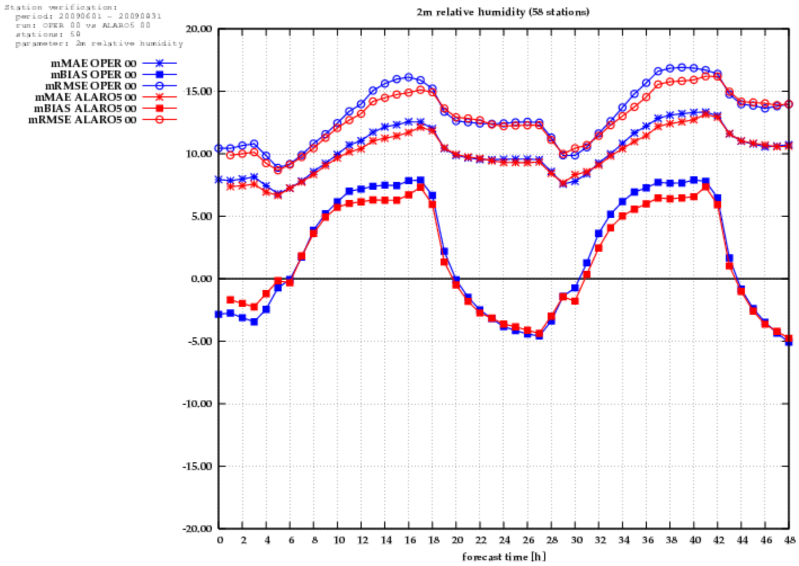


Figure 3: Mean MAE, BIAS and RMSE for relative humidity for 59 stations located in elevations ranging from 0-500m.

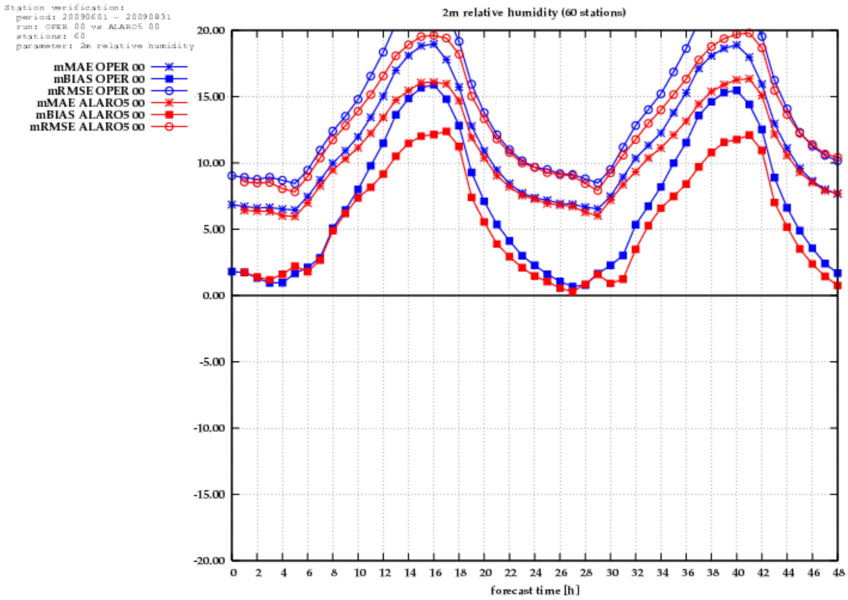


Figure 4: Mean MAE, BIAS and RMSE for relative humidity for 60 stations located in elevations ranging from 500m – 1000m.

1.4. Total cloudiness

Figures 5 and 6 show the observed and modelled climatology for total cloud cover for all stations for 20090601 - 20090731. The results for ALARO5 (red) and OPER (blue) are rather similar. For both models a u-shaped distribution is found, so 1 and 8 octets are the most frequent cloud covers simulated by the model. In ALARO5 the u-shape seems to be little bit more pronounced, so there is a tendency towards a more binary character of total cloud cover forecasts, which should be expected for higher resolution models.

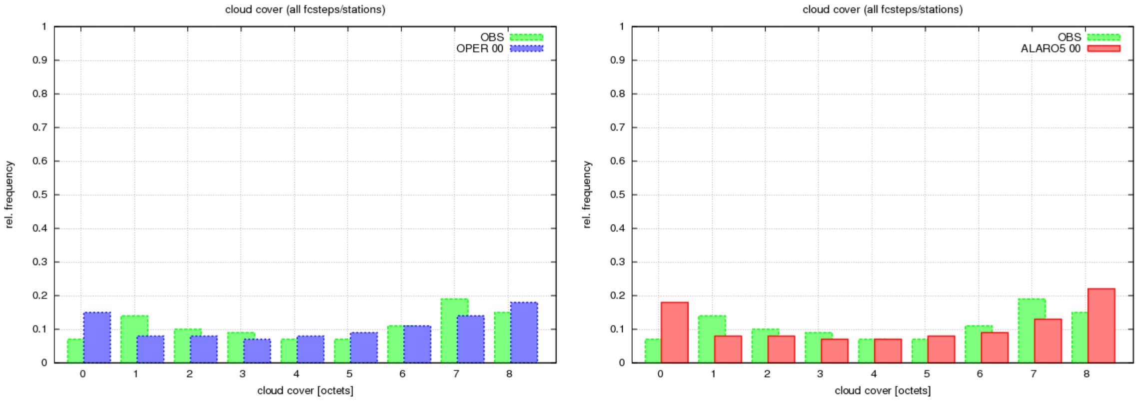


Figure 5,6: Total cloud cover climatology for 20090601 – 20090831: Observations (green), ALARO5 (red) and OPER (blue).

1.5. Temperature

2m Temperature is the only near surface parameter, where a simple height correction is applied (using a standard gradient) during the verification procedure. The results are shown in Figures 5 - 8 for the different height intervals. For stations located in lower altitudes the results for OPER and ALARO5 are very similar. The situation gets more interesting for higher stations. Figures 7 – 10 show the scores for the different height intervals: The mean scores show that during day the scores for ALARO5 and OPER are rather similar (maybe ALARO5 even slightly better for certain forecast times). During night the situation changes dramatically. ALARO5 shows a significant larger (colder) BIAS than OPER.

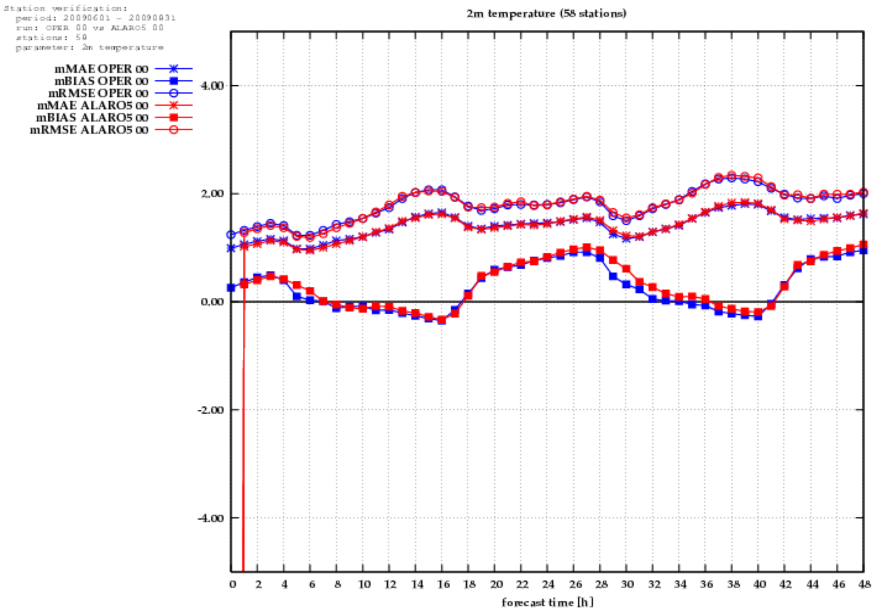


Figure 7: Mean MAE, BIAS and RMSE for 2m temperature for 60 stations located in elevations ranging from 0m – 500m.

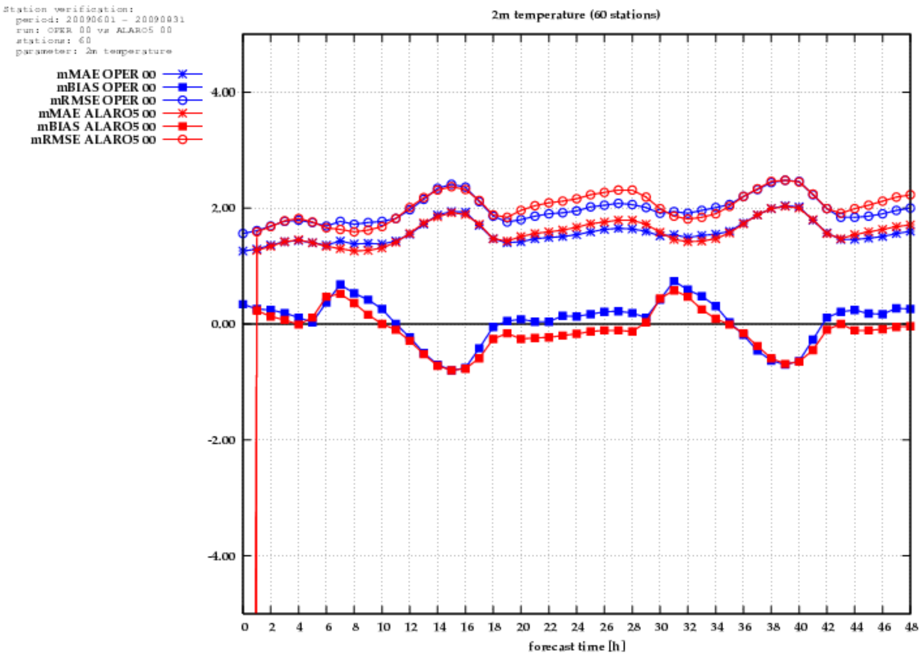


Figure 8: Mean MAE, BIAS and RMSE for 2m temperature for 60 stations located in elevations ranging from 500m – 1000m

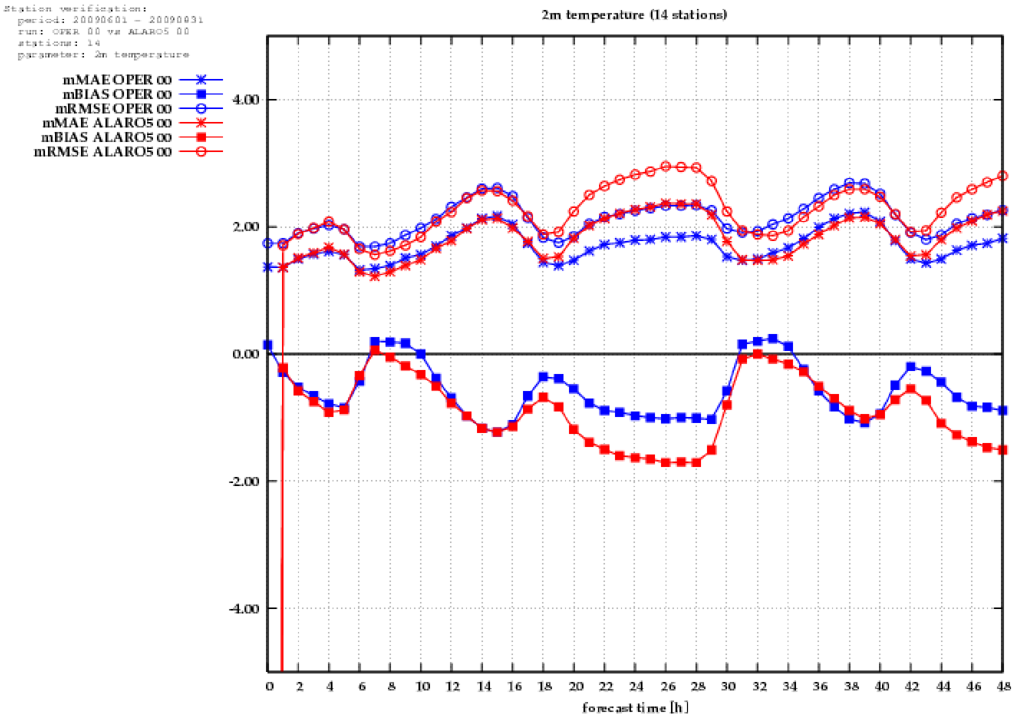


Figure 9: Mean MAE, BIAS and RMSE for 2m temperature for 60 stations located in elevations ranging from 1000 – 1500m

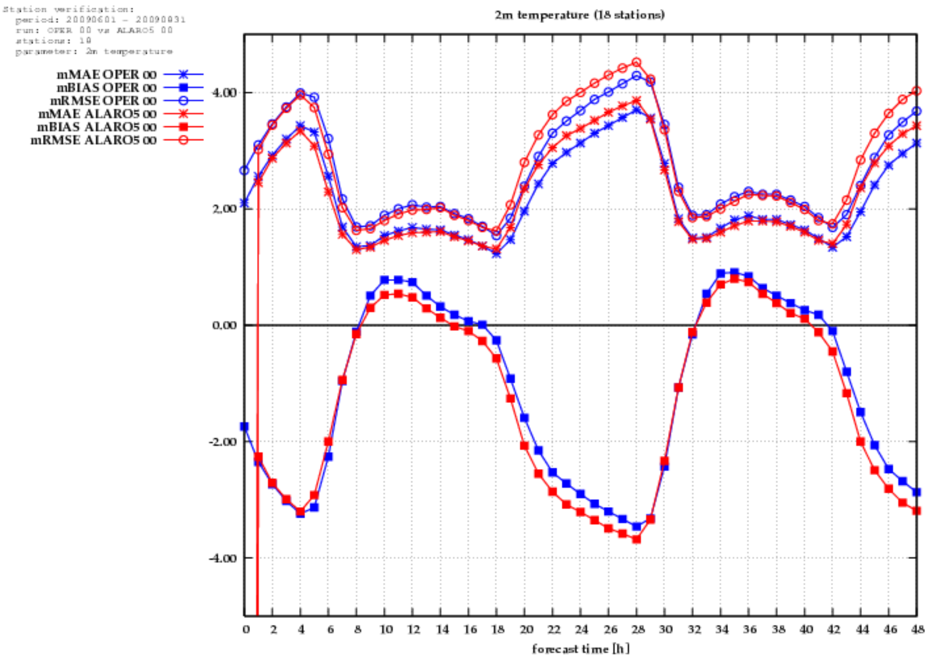


Figure 10: Mean MAE, BIAS and RMSE for 2m temperature for 60 stations located in elevations over 1500m.

When the height correction is deactivated, ALARO5 performs better. But of course one should expect a 5km version which is not easily beaten in terms of scores for 2m temperature by the operational model through a simple height correction. At this point one could argue that the operational model may also beat ALARO5 for other parameters (like 2m relative humidity), but as a height correction for humidity is usually less successful it may not be worth to continue thinking about it. Anyway, in the following the further investigations on this BIAS behaviour in ALARO5 are presented.

2. Towards a better 2m temperature diagnostics in ALARO5 (?)

2.1. General MAE characteristics

The starting point for further investigations is the fact that ALARO5 shows a significant colder BIAS than OPER during night, especially for stations in higher elevations. Figure 11 should give an impression about the type of stations showing this BIAS-characteristics for forecast step +27 (morning before sunrise). The coloured circles represent station locations, whereas the colour of the circle gives information whether the MAE for the period 20090601 – 20090831 is smaller for ALARO-5km (green), more or less equal (blue) or bigger (red) with respect to the operational model. The size of the circle should give an impression about the amplitude of the difference.

It can be seen the most of the bigger red circles are situated in Alpine regions in the Southwest or West of Austria and most of the blue (neutral) circles can be found in the regions characterized by rather flat terrain. Figure 12 shows the MAE for forecast step +15, so for the time when temperatures reach maximum values during summer. Compared to the situation shown for the step +27 there are more station showing ALARO5 with smaller MAE (green) and less stations with significant bigger MAE in ALARO5 than in OPER.

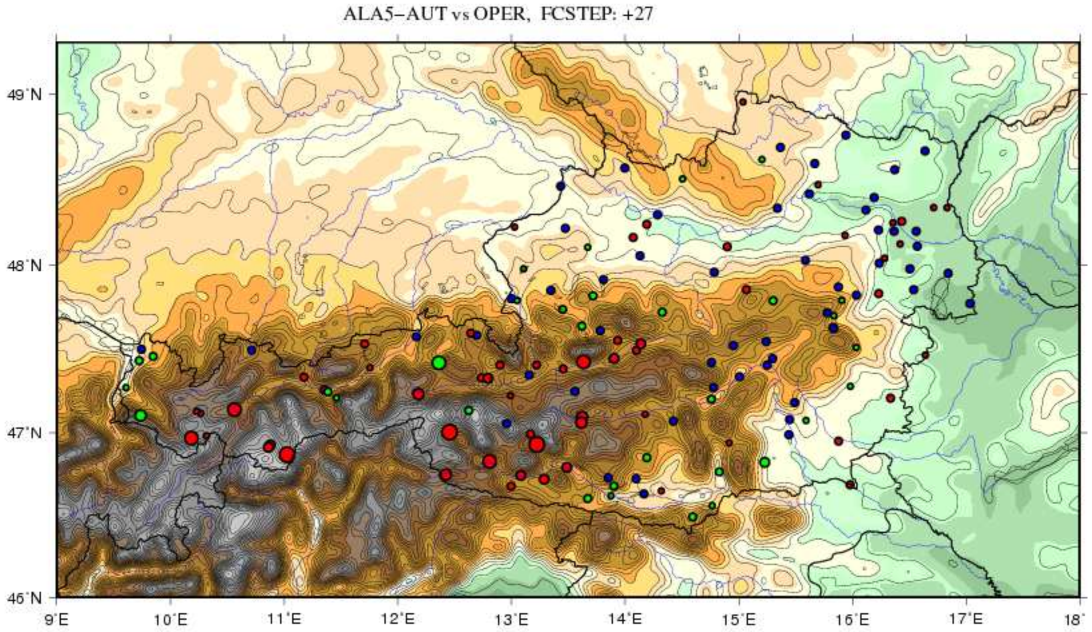


Figure 11: ALARO5 Topography + station MAE for step +27 (period 20090601 – 20090831, just 00 UTC runs); red: ALARO5 worse than OPER, green: ALARO5 better; blue: more or less equal

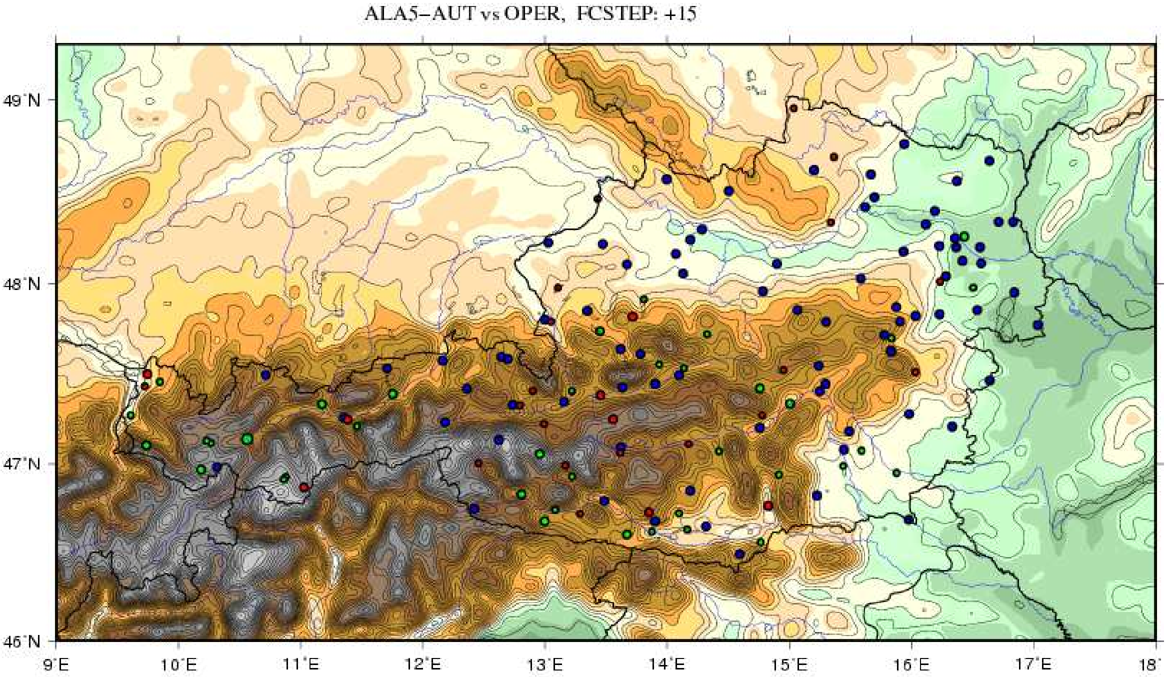
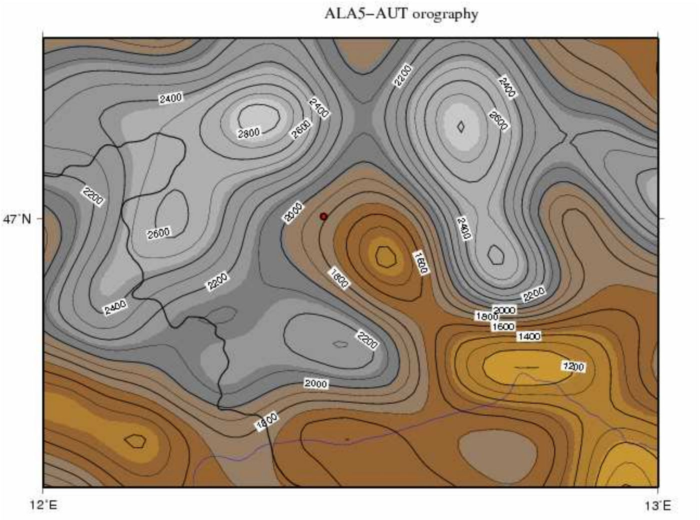
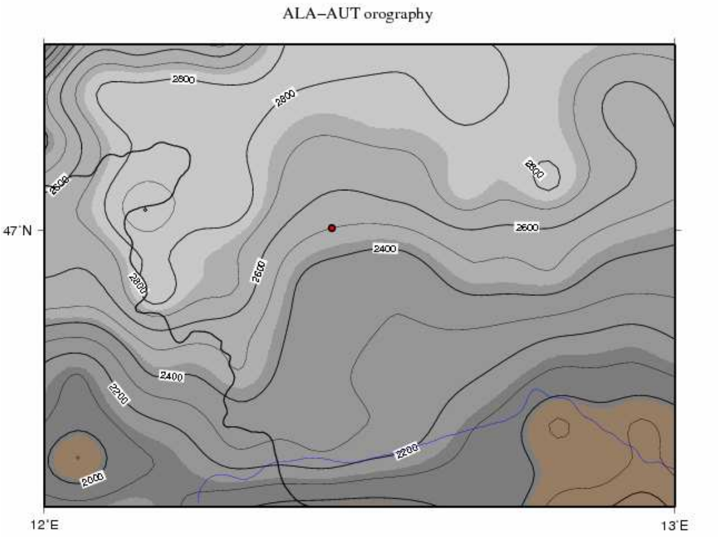


Figure 12: ALARO5 Topography + station MAE for step +15 (period 20090601 – 20090831, just 00 UTC runs); red: ALARO5 worse than OPER, green: ALARO5 better; blue: more or less equal

2.2. Station 11252 (Virgen)

In the next step, a station showing this “typical” BIAS during night was chosen for further analyses of the problem: 11252, Virgen, located in East-Tyrol in the South-western part of Austria.





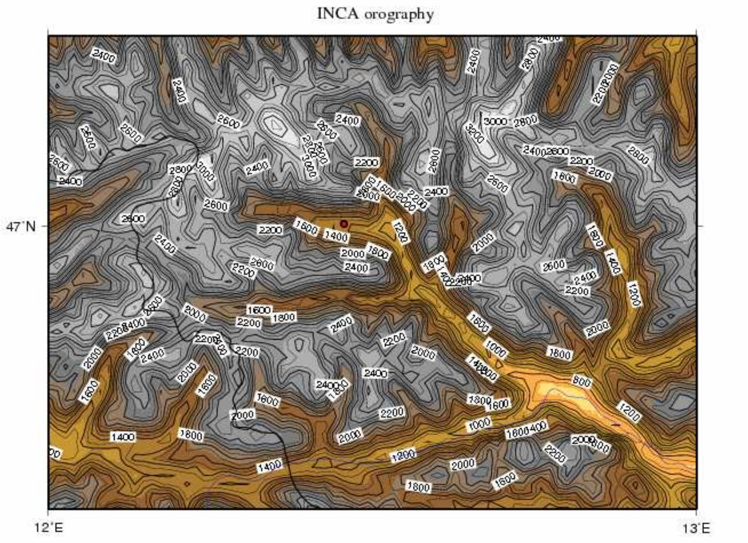


Figure 13 - 15: ALARO5 model orography (top), OPER orography (middle) and 1km resolution (INCA) topography (bottom) with location of station Virgen in East Tyrol

Figure 13, 14 and 15 show the ALARO5km, OPER and INCA 1km topography. As it can be seen in the INCA topography, Virgen is located a valley (Virgen valley), located to the south of the highest mountain peaks of the Austrian Alps (“Glocknergruppe”, “Großvenedigergruppe). The Virgen valley is connected to the Isel valley in the East which finally ends (direction southeast) in the basin of Lienz. The operational model topography (figure 14) is not able to resolve these small valleys, even the basin of Lienz is just indicated. In ALARO5-km it seems that Virgen is located in the Isel valley, as the Virgen valley is not really resolved. The Lienz basin is of course better resolved in the 5km topography.

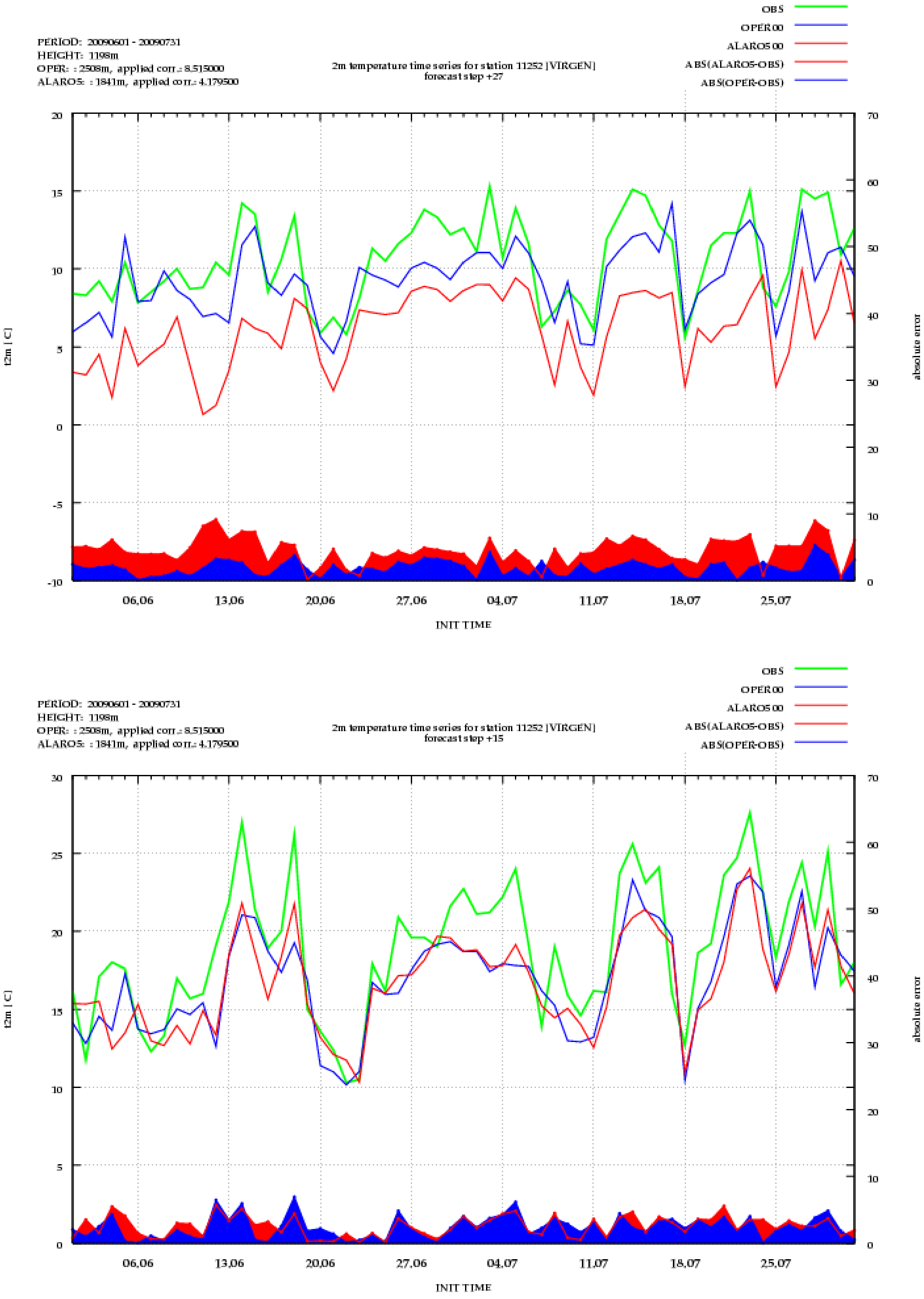


Figure 16 and 17: Time series of showing observed (green), ALARO5 (red) and OPER (blue) temperature for 03 UTC (model forecast step +27) and 15 UTC (forecast step +15)

Figure 16 shows two month 2m temperature time series (20090601 – 20090731) for the station Virgen. As already mentioned a height correction is applied (about 4K for ALARO5 and 8K for OPER). As the curves show, the 03 UTC 2m temperature is too low in ALARO5 and OPER in the majority of the cases. Figure 17 shows the time series for 15 UTC, where ALARO5 and OPER show similar results. The large cold BIAS is therefore cause by too strong (in most of the cases radiational) cooling during night time.

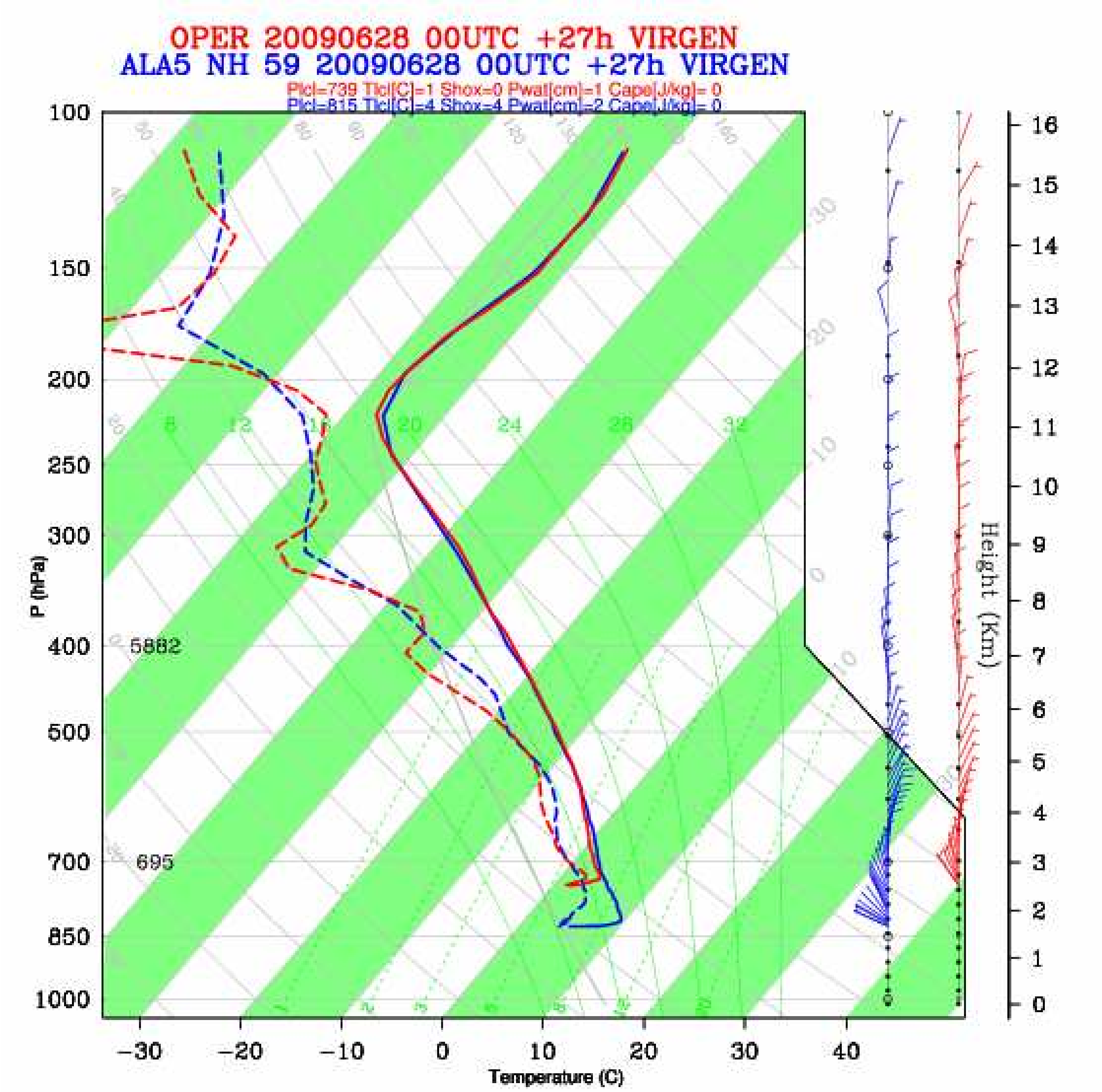


Figure 18 : Vertical profile (temperature and dewpoint) for Virgen, ALARO5 (blue) and OPER (red) at 20090628 00 UTC + 27h.

A (major??) part of this behaviour should be caused by the model topography (see Figures 13-15). As Virgen is located (more or less) in a valley in ALARO5 (or on the valley slope), whereas the valley is just indicated in OPER, radiational cooling during night should be more effective in ALARO5 (cold pool).

The large BIAS in ALARO5 can be observed at several stations in Alpine regions (see Figure 11), so there is a general overestimation of cooling in stable situations. This problem is already known from the operational model, but the higher resolution of ALARO5 topography seems to enhance the problem.

Figure 18 shows the vertical profiles for ALARO5 and OPER for Virgen for 20090628 00 UTC + 27h. In both models there is a near surface inversion, but in ALARO5 the inversion is significantly stronger. In order to change the strength of the inversion two different approaches have been chosen: 1) Change of the vertical level distribution 2) Change of interpolation method for 2m temperature.

2.3. Sensitivity of near surface inversion to vertical level distribution

In order to see the impact of the (near surface) vertical level distribution on the strength of the inversion, several vertical setups were run for a typical case: 20090628 00 UTC. The different vertical setups used are:

- OPER60: operational 60 level distribution (lowest level around 17m)
- TEST59: 59 level distribution (lowest level around 12m), more levels in PBL than operational
- TEST60: 60 level distribution (lowest level around 10m), more levels in PBL than operational
- TEST90: 90 level distribution (lowest level around 10m)

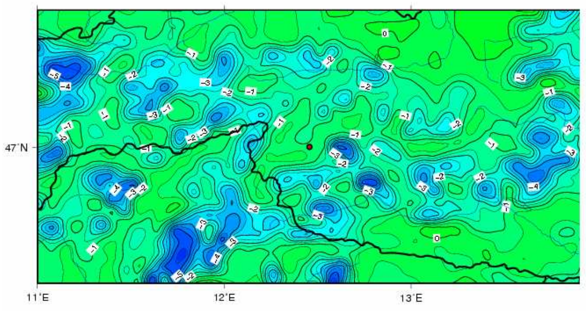
Plots for the different vertical level distributions can be found in Appendix A. In addition to the vertical level distribution several horizontal resolutions were used: 9.6km, 4.9km and 2.5km. The findings can be summarized like:

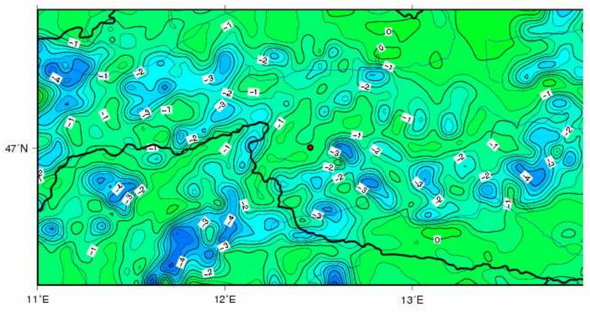
- OPER vs. ALARO5: In the operational model the strength of the inversion at station Virgen is 2.6 K, for ALARO5 4.2 K.
- OPER vs. OPER with TEST60: Inversion strength decreases by 0.2K when using TEST60 (higher T2M)
- ALARO5 with OPER60 vs. ALARO5 with TEST60 vs. ALARO5 with TEST90: Inversion decreases by 0.2K when using TEST60 and TEST90
- ALARO5 with TEST60 vs. ALARO 2.5km with TEST90: 5K Inversion when using 2.5km version.
- OPER vs. ALARO5 vs. ALARO2.5km: Inversion 2.6K, 4.2K and 5K.

The conclusion might be that for station point Virgen the strength of the near surface inversion is more sensitive to horizontal resolution. The sensitivity to the vertical resolution is rather weak.

2.4. Interpolation of temperature to the screening level

In ALADIN/ALARO, the 2m temperature is computed in the routine *acntls.F90* (see Appendix B) by interpolation between the lowest level temperature PT and the surface temperature PTS (Geleyn 1988). It is a known problem that this formulation creates significant cold BIAS for stable situations during night time. In order to decrease this BIAS a modified version of the interpolation formula was created (Kullmann 2009). The modification introduces the tuning parameter “ZAH”. Using high values for ZAH (-> infinity) reproduces the original formulation.
Several settings for ZAH were used to see the impact on the strength of the Inversion: ZAH=05, 15, 35, 100. Figures 19-22 show the difference between the temperature of the lowest model level and the 2m temperature for the different ZAH settings. A value of ZAH=100 is more or less reproducing the original formulation used in Geleyn (1988). The Figures show, that higher ZAH values produce bigger temperature differences or near surface inversion, but for Virgen (red circle) the difference remains more or less unchanged.





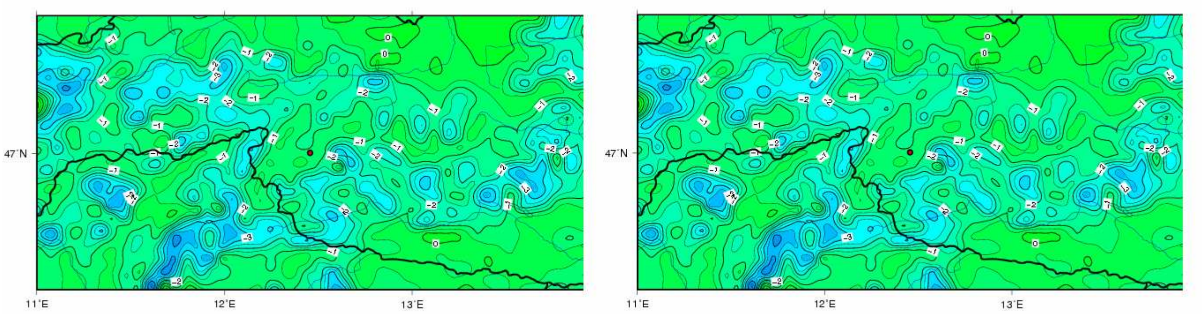


Figure 19-22 : Difference T(NLEV) – T2M for ZAH=100 (top left), ZAH=35 (top right), ZAH=15 (bottom left) and ZAH=05 (bottom right) ; 20090628 00 UTC + 26h

So in general, the use of the new interpolation formulation should be helpful (as it was shown by in Kullmann 2009 on lower horizontal resolution) to reduce the BIAS for some stations during night.
In order to test this a one week period characterized by clear and stable night conditions was chosen and an ALARO-5km version was running with the tuning parameter set to ZAH=35. Figure 23 shows MAE, BIAS and RMSE for ALARO5 and EX77 (ALARO5 with ZAH=35) for a one week period in July 2009.

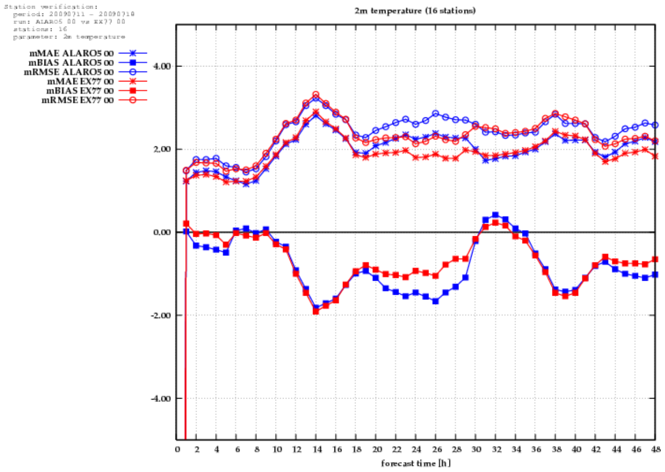


Figure 23: Mean MAE, BIAS and RMSE for 2m temperature for 16 stations located in elevations ranging from 1500 – 1000m. Verification period: 20090711 – 20090718. ALARO5 (blue), ALARO5 running with ZAH=35 (red)

It can be seen that the cold BIAS during night is significantly reduced. For case 20090628 00 UTC we could see that using the modified interpolation formulation for 2m temperature did not have any effect for station point Virgen.

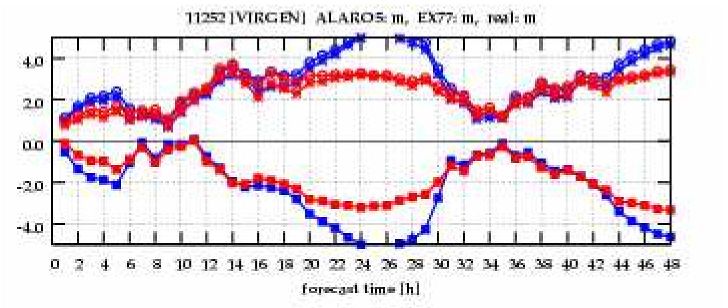


Figure 23: Mean MAE, BIAS and RMSE for 2m temperature for 16 stations located in elevations ranging from 1500 – 1000m. Verification period: 20090711 – 20090718. ALARO5 (blue), ALARO5 running with ZAH=35 (red)

Figure 23 shows BIAS, MAE and RMSE for Virgen for the same one week period. A significant reduction of BIAS (and MAE, RMSE) can be observed.

A further test was made to get an idea whether using the lowest level temperature instead of the interpolation between lowest model level and surface would bring any improvement. Figure 24 again shows the scores for the one week period in July 2009. This time ALARO5 is compared with a version using the lowest level temperature instead of the interpolation to measurement height. Figure 24 shows that for the stations located in elevations ranging from 1000 – 1500m the lowest model level temperature would be the better choice during night time, but during day one would introduce a stronger negative Bias.

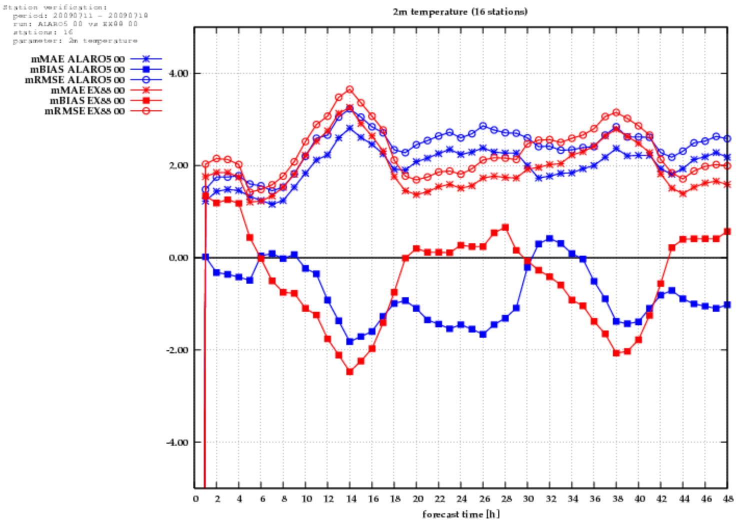


Figure 24: Mean MAE, BIAS and RMSE for 2m temperature for 16 stations located in elevations ranging from 1500 – 1000m. Verification period: 20090711 – 20090718. ALARO5 (blue), ALARO5 running without interpolation to 2m (red)

An interesting side-effect of this "lowest model level" experiment is found for wind speed. From Figure 2 we learned that with the high resolution version ALARO5 we have neutral to slightly worse scores for wind speed, mainly caused by an underestimation of wind speed.

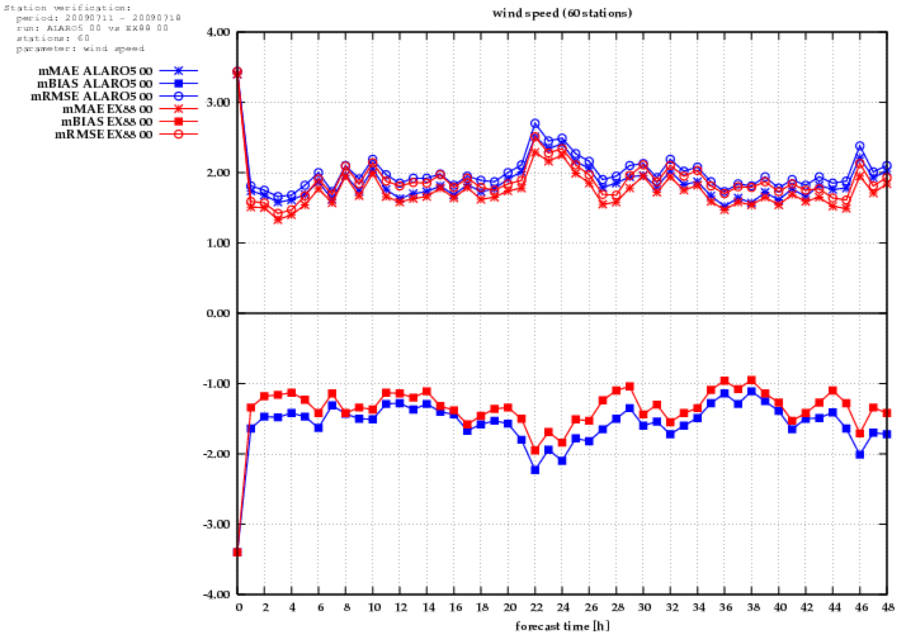


Figure 25: Mean MAE, BIAS and RMSE wind speed for 60 stations located in elevations ranging from 500 – 1000m. Verification period: 20090711 – 20090718. ALARO5 (blue), ALARO5 running without "interpolation to 10m" (red).

Figure 25 shows the scores for wind speed for the period 20090711 – 20090718 for ALARO5 and for an ALARO5 version where no interpolation to measurement height is done. It can be seen that the negative Bias (and so MAE and RMSE) are reduce significantly. This is true especially for stations in mountainous areas.

3. Conclusions

Summarizing the results from the previous sections the following conclusions can be drawn:

- ALARO5 shows significant better performance for surface parameters like MSLP, RH2M, especially in mountainous areas where one might expect a benefit through the higher resolution (of topography). Even in rather flat terrain a (slight) positive impact can be found.
- For wind speed the scores are rather neutral in flatland areas. In mountainous areas, where one might expect a better resolution of topographically (induced)/modified (thermal)/synoptical wind circulation the scores are slightly worse, mainly cause by a stronger negative Bias. This negative Bias can be reduced (to a Bias in magnitudes of the operational 9.6km version), when skipping the interpolation of wind speed to measurement height and using the lowest model level wind instead.
- For temperature the impact of high resolution is neutral in flatland areas. For stations located in higher elevations or in alpine valleys/basins there is a general tendency for a significant cold Bias for night time temperatures (in stable conditions). This strong Bias leads to the fact that when a simple height correction is applied, the operational 9.6km model performs better than ALARO5.
- A further analysis of the problem shows that the cold Bias is caused by an overestimation of near surface inversion during nights characterized by radiative cooling.
- The inversion can hardly be modified when using different vertical resolutions.
- The influence of horizontal resolutions (topography) on the inversion (9.6km, 4.9km, 2.5km) seems to be stronger than the vertical resolution.
- The Bias problem during stable night time conditions is already known from the operational 9.6km model, but this problem gets even more evident for 4.9km resolution.
- A modification of the interpolation formula from model levels to measurement height (as described in Kullmann 2009 and operationally used by CZ) gets more important for the 4.9km version. The cold Bias can be significantly reduced (to the Bias of the operational 9.6km model).
- Switching of the interpolation of wind speed from the lowest model level to measurement height is beneficial for wind speed in mountainous areas.

References

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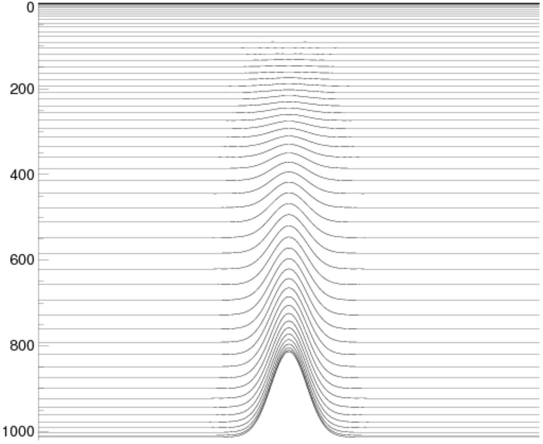
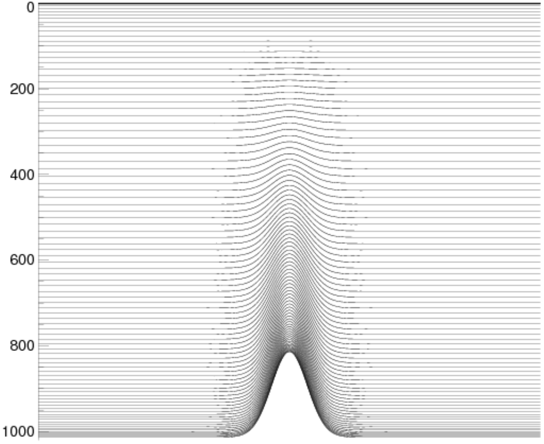
Kullmann, L. (2009): New interpolation formula in stable situations for the calculation of diagnostic fields at measurement height. Presentation at the 19th ALADIN Wirkshop & HIRLAM ASM 2009, Utrecht. Available from http://www.cnrm.meteo.fr/aladin/IMG/pdf/ME_LKu.pdf.

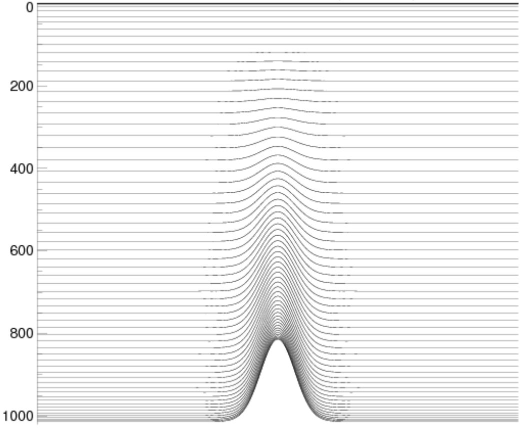
Wittmann, C., Haiden, T., Kann, A. (2010): Evaluating multi-scale precipitation forecasts using high resolution analysis. *Subm. to Advances in Science and Research.*

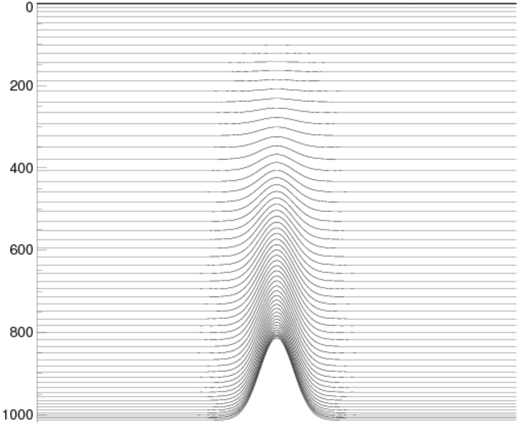
Wernli, H., Paulat, M., Hagen, M. and Frei, C. (2008): SAL - A novel quality measure for the verification of quantitative precipitation forecasts. Mon. Wea. Rev., 136, 4470-4487, 2008.

APPENDIX A


ALADIN−AUSTRIA oper (60 levels)


ALARO−AUSTRIA 5km VFE (90 levels)


ALADIN−AUSTRIA neu (60 levels)


ALARO−AUSTRIA 5km (59 levels)

APPENDIX B

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!OPTIONS XOPT(NOEVAL)
SUBROUTINE ACNTCLS ( KIDIA,KFDIA,KLON,KTDIA,KLEV,&
 !----------------------------------------------------------------------
 ! - INPUT  2D .
 & PAPRS,PAPRSF,PCP,PQ,PT,PU,PV,&
 ! - INPUT  1D .
 & PCD,PCDN,PCDNH,PCH,PCPS,PDPHI,PDPHIT,PDPHIV,&
 & PQS,PSTAB,PTS,&
 ! - OUTPUT 1D .
 & PQCLS,PRHCLS,PTCLS,PUCLS,PVCLS,PZPCLS,&
 ! - LOCK ARGUMENTS .
 & CDLOCK)

!**** *ACNTCLS * - INTERP. DES PARAMETRES U,V,T,Q AUX HAUTEURS CHOISIES.

!     Sujet.
!     ------

!     - ROUTINE DE CALCUL ACTIF .
!          INTERPOLATION DES TEMPERATURES, HUMIDITES (SPECIFIQUES ET
!          RELATIVES) ET VENTS AUX HAUTEURS "METEO" .

!          TEMPERATURE, MOISTURE (SPECIFIC AND RELATIVE) AND WIND
!          INTERPOLATION AT STANDARD "METEOROLOGICAL" LEVELS .

!**   Interface.
!     ----------
!        *CALL* *ACNTCLS*

!-----------------------------------------------------------------------
! WARNING: THE ENGLISH VERSION OF VARIABLES' NAMES IS TO BE READ IN THE
!          "APLPAR" CODE.
!-----------------------------------------------------------------------

! -   ARGUMENTS D'ENTREE.
!     -------------------

! - NOM DES PARAMETRES DE DIMENSIONNEMENT DE LA PHYSIQUE.

! KIDIA      : INDICE DE DEPART DES BOUCLES VECTORISEES SUR L'HORIZONT..
! KFDIA      : INDICE DE FIN DES BOUCLES VECTORISEES SUR L'HORIZONTALE.
! KLON       : DIMENSION HORIZONTALE DES TABLEAUX.
! KTDIA      : INDICE DE DEPART DES BOUCLES VERTICALES (1 EN GENERAL).
! KLEV       : DIMENSION VERTICALE DES TABLEAUX "FULL LEVEL".

! - NOM DES VARIABLES DE LA PHYSIQUE (PAR ORDRE ALPHABETIQUE DANS CHAQUE
!   CATEGORIE).

! - 2D (0:KLEV) .

! PAPRS      : PRESSION AUX DEMI-NIVEAUX.
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! - 2D (1:KLEV) .

! PAPRSF     : PRESSION AUX NIVEAUX.
! PCP        : CHALEUR MASSIQUE A PRESSION CONSTANTE DE L'AIR.
! PQ         : HUMIDITE SPECIFIQUE DE LA VAPEUR D'EAU.
! PT         : TEMPERATURE.
! PU         : COMPOSANTE EN X DU VENT.
! PV         : COMPOSANTE EN Y DU VENT.

! - 1D (DIAGNOSTIQUE) .

! PCD        : COEFFICIENT D'ECHANGE EN SURFACE POUR U ET V.
! PCDN       : COEFFICIENT NEUTRE D'ECHANGE EN SURFACE.
! PCDNH      : COEFFICIENT THERMIQUE NEUTRE D'ECHANGE EN SURFACE.
! PCH        : COEFFICIENT D'ECHANGE EN SURFACE POUR T ET Q.
! PCPS       : CHALEUR MASSIQUE A PRESSION CONSTANTE DE L'AIR AU SOL.
! PQS        : HUMIDITE SPECIFIQUE DE SURFACE.
! PSTAB      : INDICE DE STABILITE A LA SURFACE.

! - 1D (PROGNOSTIQUE) .

! PTS        : TEMPERATURE DE SURFACE.

! - 1D (SPECIFIQUE) .

! PDPHIT     : HAUTEUR D INTERPOLATION POUR T ET Q (EN GEOPOTENTIEL).
! PDPHIT     : HAUTEUR D INTERPOLATION POUR T ET Q (EN GEOPOTENTIEL).
! PDPHIV     : HAUTEUR D INTERPOLATION POUR U ET V (EN GEOPOTENTIEL).

!-----------------------------------------------------------------------

! -   ARGUMENTS DE SORTIE.
!     --------------------

! - NOM DES VARIABLES DE LA PHYSIQUE (PAR ORDRE ALPHABETIQUE DANS CHAQUE
!   CATEGORIE).

! - 1D (DIAGNOSTIQUE) .

! PQCLS      : SORTIE DIAGNOSTIQUE DE L'HUMIDITE SPECIFIQUE A HTQ METEO.
! PRHCLS     : SORTIE DIAGNOSTIQUE DE L'HUMIDITE RELATIVE A HTQ METEO.
! PTCLS      : SORTIE DIAGNOSTIQUE DE LA TEMPERATURE A HTQ METEO.
! PUCLS      : SORTIE DIAGNOSTIQUE DU VENT EN X A HUV METEO.
! PVCLS      : SORTIE DIAGNOSTIQUE DU VENT EN Y A HUV METEO.
! PZPCLS     : SORTIE DIAGNOSTIQUE DE PRESSION A HTQ METEO.

!-----------------------------------------------------------------------

! -   ARGUMENTS IMPLICITES.
!     ---------------------

! COMMON/YOMPHY /
! COMMON/YOMCST /
```

```
! COMMON/YOMPHY0/
! COMMON/FCTTRM /

!-----------------------------------------------------------------------

!     Externes.
!     ---------

!     Methode.
!     --------

!     Auteur.
!     -------
!        92-05, J.F. Geleyn.

!     Modifications.
!     --------------
!        97-08, PZx variables > Zx, introduce CDLOCK - J.M. Piriou.
!        98-08, Pressure at HTQ                      - V. Lorant
!        M.Hamrud      01-Oct-2003 CY28 Cleaning

!-----------------------------------------------------------------------

USE PARKIND1  ,ONLY : JPIM     ,JPRB
USE YOMHOOK   ,ONLY : LHOOK,   DR_HOOK

USE YOMPHY   , ONLY : LNEIGE,  LBLVAR
USE YOMCST   , ONLY : RV       ,RCPD     ,RCPV     ,RETV     ,&
 & RCW      ,RCS      ,RLVTT    ,RLSTT    ,RTT      ,&
 & RALPW    ,RBETW    ,RGAMW    ,RALPS    ,RBETS    ,&
 & RGAMS    ,RALPD    ,RBETD    ,RGAMD
USE YOMPHY0  , ONLY : VKARMN

IMPLICIT NONE

INTEGER(KIND=JPIM),INTENT(IN)    :: KLON
INTEGER(KIND=JPIM),INTENT(IN)    :: KLEV
INTEGER(KIND=JPIM),INTENT(IN)    :: KIDIA
INTEGER(KIND=JPIM),INTENT(IN)    :: KFDIA
INTEGER(KIND=JPIM)               :: KTDIA ! Argument NOT used
REAL(KIND=JPRB)   ,INTENT(IN)    :: PAPRS(KLON,0:KLEV)
REAL(KIND=JPRB)   ,INTENT(IN)    :: PAPRSF(KLON,KLEV)
REAL(KIND=JPRB)   ,INTENT(IN)    :: PCP(KLON,KLEV)
REAL(KIND=JPRB)   ,INTENT(IN)    :: PQ(KLON,KLEV)
REAL(KIND=JPRB)   ,INTENT(IN)    :: PT(KLON,KLEV)
REAL(KIND=JPRB)   ,INTENT(IN)    :: PU(KLON,KLEV)
REAL(KIND=JPRB)   ,INTENT(IN)    :: PV(KLON,KLEV)
REAL(KIND=JPRB)   ,INTENT(IN)    :: PCD(KLON)
REAL(KIND=JPRB)   ,INTENT(IN)    :: PCDN(KLON)
REAL(KIND=JPRB)   ,INTENT(IN)    :: PCDNH(KLON)
REAL(KIND=JPRB)   ,INTENT(IN)    :: PCH(KLON)
REAL(KIND=JPRB)   ,INTENT(IN)    :: PCPS(KLON)
REAL(KIND=JPRB)   ,INTENT(IN)    :: PDPHI(KLON)
REAL(KIND=JPRB)   ,INTENT(IN)    :: PDPHIT(KLON)
REAL(KIND=JPRB)   ,INTENT(IN)    :: PDPHIV(KLON)
REAL(KIND=JPRB)   ,INTENT(IN)    :: PQS(KLON)
REAL(KIND=JPRB)   ,INTENT(IN)    :: PSTAB(KLON)
REAL(KIND=JPRB)   ,INTENT(IN)    :: PTS(KLON)
REAL(KIND=JPRB)   ,INTENT(OUT)   :: PQCLS(KLON)
REAL(KIND=JPRB)   ,INTENT(OUT)   :: PRHCLS(KLON)
REAL(KIND=JPRB)   ,INTENT(OUT)   :: PTCLS(KLON)
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REAL(KIND=JPRB)   ,INTENT(OUT)   :: PUCLS(KLON)
REAL(KIND=JPRB)   ,INTENT(OUT)   :: PVCLS(KLON)
REAL(KIND=JPRB)   ,INTENT(OUT)   :: PZPCLS(KLON)
CHARACTER(LEN=7)  ,INTENT(IN)    :: CDLOCK
INTEGER(KIND=JPIM) :: JLON

REAL(KIND=JPRB) :: ZBD, ZBH, ZBN, ZBNH, ZCORS, ZCORU, ZCPVMD,&
 & ZDELTA, ZEW, ZIV, ZLOGS, ZLOGU, ZRS, ZRU
REAL(KIND=JPRB) :: ZHOOK_HANDLE

#include "abor1.intfb.h"

#include "fcttrm.h"


!     CHECK RELIABILITY OF INPUT ARGUMENTS.

IF (LHOOK) CALL DR_HOOK('ACNTCLS',0,ZHOOK_HANDLE)
IF(CDLOCK /= 'ACNTCLS') CALL ABOR1('BAD NUMBER OF ARGUMENTS!')

!*
!     -----------------------------------------------------------------
!     I - CONSTANTES AUXILIAIRES.

!         AUXILIARY CONSTANTS.

ZCPVMD=RCPV-RCPD

!*
!     -----------------------------------------------------------------
!     II - INTERPOLATION.

!          INTERPOLATION.

DO JLON=KIDIA,KFDIA

!     CALCULS PREPARATOIRES.
!     PREPARATORY CALCULATIONS.

  ZBN=VKARMN/SQRT(PCDN(JLON))
  ZBNH=VKARMN*SQRT(PCDN(JLON))/PCDNH(JLON)
  ZBD=VKARMN/SQRT(PCD(JLON))
  ZBH=VKARMN*SQRT(PCD(JLON))/PCH(JLON)
  ZRU=PDPHIV(JLON)/PDPHI(JLON)
  ZRS=PDPHIT(JLON)/PDPHI(JLON)
  ZLOGU=LOG(1.0_JPRB+ZRU*(EXP(ZBN)-1.0_JPRB))
  ZLOGS=LOG(1.0_JPRB+ZRS*(EXP(ZBNH)-1.0_JPRB))
  ZCORU=PSTAB(JLON)*ZRU*(ZBN-ZBD)+(1.0_JPRB-PSTAB(JLON))*LOG(1.0_JPRB+ZRU &
   & *(EXP(MAX(0.0_JPRB,ZBN-ZBD))-1.0_JPRB))
  ZCORS=PSTAB(JLON)*ZRS*(ZBNH-ZBH)+(1.0_JPRB-PSTAB(JLON))*LOG(1.0_JPRB+ZRS &
   & *(EXP(MAX(0.0_JPRB,ZBNH-ZBH))-1.0_JPRB))

!     INTERPOLATION DES COMPOSANTES DU VENT.
!     INTERPOLATION OF WIND COMPONENTS.

  ZIV=MAX(0.0_JPRB,MIN(1.0_JPRB,(ZLOGU-ZCORU)/ZBD))
  PUCLS(JLON)=PU(JLON,KLEV)*ZIV
  PVCLS(JLON)=PV(JLON,KLEV)*ZIV

```

```
!     INTERPOLATION DES VARIABLES THERMODYNAMIQUES.
!     INTERPOLATION OF THERMODYNAMIC VARIABLES.

  ZIV=MAX(0.0_JPRB,MIN(1.0_JPRB,(ZLOGS-ZCORS)/ZBH))
  IF (LBLVAR) THEN
     PQCLS(JLON)=PQ(JLON,KLEV)
     PTCLS(JLON)=PT(JLON,KLEV)
  ELSE
     PQCLS(JLON)=PQS(JLON)+ZIV*(PQ(JLON,KLEV)-PQS(JLON))
     PTCLS(JLON)=(PCPS(JLON)*PTS(JLON)+ZIV*(PCP(JLON,KLEV)&
     & *PT(JLON,KLEV)-PCPS(JLON)*PTS(JLON)+PDPHI(JLON))&
     & -PDPHIT(JLON))/(RCPD+ZCPVMD*PQCLS(JLON))
  ENDIF

!     CALCUL DE L'HUMIDITE RELATIVE.
!     RELATIVE HUMIDITY COMPUTATION.

  IF (LNEIGE) THEN
    ZDELTA=MAX(0.0_JPRB,SIGN(1.0_JPRB,RTT-PTCLS(JLON)))
  ELSE
    ZDELTA=0.0_JPRB
  ENDIF

  PZPCLS(JLON)=PAPRS(JLON,KLEV)+ZRS*(PAPRSF(JLON,KLEV)-PAPRS(JLON,KLEV))
  ZEW= FOEW (PTCLS(JLON),ZDELTA)
  PRHCLS(JLON)=(PZPCLS(JLON)*PQCLS(JLON)*(RETV+1.0_JPRB))/&
   & (ZEW*(1.0_JPRB+RETV*PQCLS(JLON)))
ENDDO

IF (LHOOK) CALL DR_HOOK('ACNTCLS',1,ZHOOK_HANDLE)
END SUBROUTINE ACNTCLS
```