ANNEX

Implementation of the non saturated downdraught in the CHMI Alaro reference operational version (CY36T1ope_op8)

Luc Gerard and Doina Banciu

1. Introduction

In November - December 2013, during the Prague stays of Luc Gerard and Doina Banciu, the last developments of Luc Gerard on complementary sub-grid draughts were implemented in the operational Alaro version CY36ope1_op8.

As agreed during the Alaro-1 working days in Slovenia (June 2012) it was decided to include in the Alaro-1, as a first step, only the non-saturated downdraught part. In this sense a clean version is prepared, removing some temporary options and adding few correction as described below in sections 2-4. In section 5 is presented the code validation in comparison with the results obtained in December 2013. It turned out that a re-tuning of downdraught and other parts is necessary. The section 6 contains the results of a first re-tuning while final tuning will be done later when last modifications of radiation and turbulence parameterizations will have been included in Alaro-1.

2. The non saturated downdraught routine: (ACNSDO)

The non-saturated downdraught routine is activated by the **LNSDO** key.
The routine allows the parameterization of the usual prognostic downdraught and the complementary sub-grid downdraught under the key **LCSD**.

We decided to renounce to the tested option of advection of the mass flux instead of draught velocity advection, taking into account the small impact on the results and the increase of computing time.

Specific free parameters

GDDALBU : COEFF OF BUOYANCY ACCOUNTING FOR VARIOUS EFFECTS
GDDFRAC : FRACTION OF PRECIPITATION AREA OCCUPIED BY DD
GDDENDYMX: LIMITATION OF DYNAMICAL ENTRAIMENT IN DD
GDDFP(1:2) : GAIN AND EXPONENT OF F(PRECIP) IN ACNSDO
GDDPROM(1:2): GDDPROM(1)=MAX VALUE OF OMEGA_D

Other used parameters, previously defined:

GCVADS, TDDGP, TDDBU, TDDFR , TENTRD, GDDBETA, GDDDP, GDDFRAC, GDDFP

The recommended set up established in December 2013:

namphy

LNSDO=.TRUE,
LCDDEVPRO=.TRUE.
LCAPE=.FALSE.

namphy0

GCVADS=0.8,

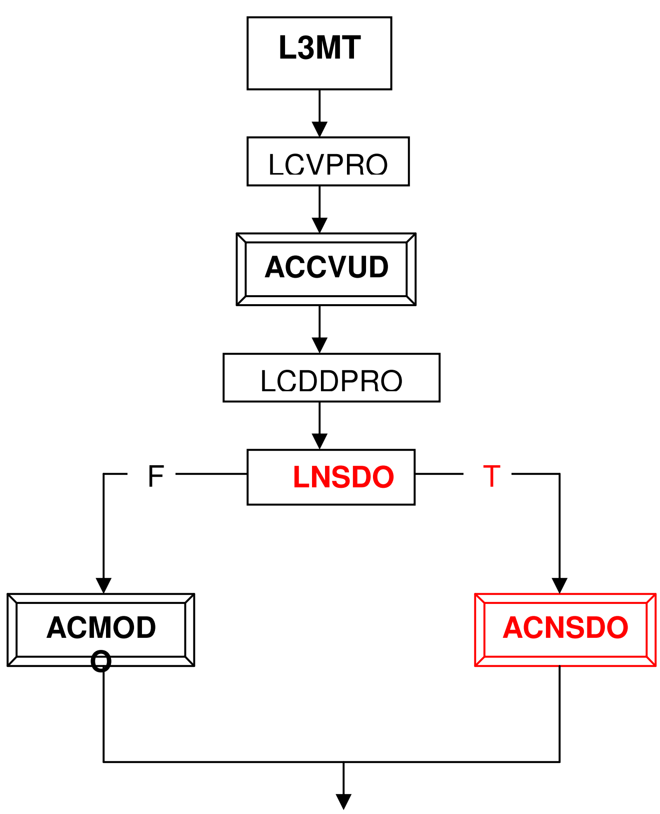
GCVTAUDE=900.,
GDDALBU=0.9,
GDDBETA=5.,
GDDDP=8.E15,
GDDENDYMX=1.E-4
GDDFRAC=0.33,
GDDFP(1)=4.398E-2
GDDFP(2)=0.75
GDDPROM(1)=180 ! Pa/s
GDDPROM(2)=0.02
TDDFR=1.E-4,
TDDGP=0.8,
TENTRD=0.5E-04
QXRTAUIFR=900., ! (see the explanation in section 4 – yomphy0)

namgfl

In order to prevent the negative values it was chosen the 'quasi monotonic' or 'shape preserving' option for the advection of draught velocity, draught mesh fraction and `pseudo-historical' convective cloudiness.

YDAL_NL%LQM=.T.,
YDOM_NL%LQM=.T.,
YUAL_NL%LQM=.T.,
YUOM_NL%LQM=.T.,
YUNEBH_NL%LQM=.T.,

3. Aplpar sequence



The aplpar routine was modified accordingly to the above sequence with other small modifications. One of them concerns the option LCVGQD, representing a coding simplification since GCOMOD can be only 0 or 1.

Differences with respect to the reference version CY36T1Ope_op8 (always the new version at left and reference at right):

```
17,18c17,18
<  & PDDAL  , PDDOM  ,  PENTCH , PUDAL  , PUDOM  , &
<  & PUNEBH, PEVEL0, PRKTH  , PRKTQV , PRKTQC ,&
---
>  & PDDAL  , PDDOM  , PENTCH , PUDAL  , PUDOM  , PUNEBH, PEVEL0, &
>  & PRKTH  , PRKTQV , PRKTQC ,&
20c20
<  & PPBLH  , &
---
>  & PPBLH  ,&
803c803
<  &         L3MT     ,LCVPRO   ,LCDDPRO  ,LNSDO    ,LENTCH   ,&
---
>  &         L3MT     ,LCVPRO   ,LCDDPRO  ,LENTCH   ,&
819,821c819,820
<  &         AERCS5   ,GCOMOD   ,&
<  &         HUCOE    ,HUTIL    ,HUTIL1  ,HUTIL2 ,&
<  &         RTCAPE   ,UHDIFV   ,XMINLM   ,XMAXLM   ,XKLM
---
>  &          AERCS5   ,GCOMOD   ,HUCOE    ,HUTIL    ,HUTIL1  ,HUTIL2   ,&
>  &          RTCAPE   ,UHDIFV   ,XMINLM   ,XMAXLM   ,XKLM
1092c1091
< REAL(KIND=JPRB)   ,INTENT(OUT)   :: PDIAGH(KLON)
---
> REAL(KIND=JPRB)   ,INTENT(OUT)   :: PDIAGH(KLON)
1373c1372
< LOGICAL :: LLCLS, LLHMT, LLZERO
---
> LOGICAL :: LLCLS, LLHMT, LLZERO
1518d1516
< #include "acnsdo.intfb.h"
1918d1915
<
3230c3227
<      IF(.NOT.LCVGQD) THEN
---
>    IF(.NOT.LCVGQD) THEN
3235c3232
<          & /(1.0_JPRB+PGM(JLON)*TEQK*GCOMOD) &
---
>          & /(1.0_JPRB+PGM(JLON)*TEQK)**GCOMOD &
3243,3249c3240,3242
<      IF (GCOMOD==1._JPRB) THEN
<        DO JLON = KIDIA, KFDIA
<          ZTAUX(JLON)=RTCAPE*(1._JPRB+((PGM(JLON)*TEQC)-1._JPRB))
<        ENDDO
<      ELSE
<         ZTAUX=RTCAPE
<      ENDIF
---
>      DO JLON = KIDIA, KFDIA
>        ZTAUX(JLON)=RTCAPE*(PGM(JLON)*TEQC)**GCOMOD
>      ENDDO
3256,3257c3249
<    ! ZSIGPC: CONVECTIVE FRACTION OF PRECIPITATION FLUX, USED FOR A POSTERIORI
<    ! ZSIGP : PRECIPITATION MESH FRACTION
---
>    ! ZSIGPC: PROGNOSTIC CONVECTIVE PRECIPITATBLE AREA, USED FOR A POSTERIORI
```

```
3273a3266
>     & PDDAL, &
3280c3273
<
---
>
3393,3406d3385
<    IF (LNSDO) THEN
<      CALL ACNSDO(KIDIA,KFDIA,KLON,KTDIA,KLEV,&
<       & PALPH,PAPHI,PAPHIF,PAPRS,PAPRSF,PCP,&
<       & PDELP,PLNPR,ZQV,ZQI,ZQL,ZQR,ZQS,ZQW,&
<       & PR,PRDELP, ZSIGP,&
<       & ZT,PTS,ZTW,ZU,ZV,PEVEL0,&
<       & ZATSLC,ZGEOSLC,&
<       & PFPLSL,PFPLSN,ZFHP,&
<       & ZDIFCQD,ZDIFCQLD,ZDIFCQID,ZDIFCSD,&
<       & PFPEVPCL,PFPEVPCN,&
<       & ZSTRCUD,ZSTRCVD,&
<       & PDDAL,PDDOM )
<    ELSE
<
3417c3396
<    ENDIF
```

4. Other modified routines

Once new parameters were introduced the corresponding modules (yomphy, yomphy0), the setup routines (su0phy, suphy0) and the namelists (namphy, namphy0) were modified. The not used parameter were deleted.

Differences with the reference versions:

yomphy

```
27d26
< !      LRITO   : KEY FOR RISING UPDRAFT TOP IN PROGNOSTIC CONVECTION
84,87d82
< !      LNEBINS : CLE POUR UTILISATION DE LA FRACTION NUAGEUSE CONVETIVE DANS
< !                LA MICROPHYSIQUE (CONVECTION PRONOSTIQUE)
< !              : KEY CONTROLLING THE CONVECTION CLOUD FRACTION FOR MICROPHYSICS
< !                (PROGNOSTIC CONVECTION)
201a197
> !                ( ACCVUD  ).
204,211c200
< !      LNSDO   : CLE D'APPEL DU DOWNDRAFT PRONOSTIQUE NONSATURE
< !              : KEY FOR CALLING PROGNOSTIC NONSATURATED DOWNDRAFT
< !                LNSDO=.T. => ACNSDO; LNSDO=.F. => ACMODO
< !      LCSD    : CLE D'APPEL DU DOWNDRAFT NON SATURE COMPLEMENTAIRE
< !                SOUS-MAILLE
< !                (AVEC LCDDPRO=.T. et LNSDO-.T.)
< !                KEY FOR CALLING THE NON SATURATED COMPLEMENTARY SUBGRID
< !                DOWNDRAFT
---
> !                ( ACMODO  ).
392d380
< LOGICAL :: LNEBINS
501,504d488
< LOGICAL :: LRITO
< LOGICAL :: LNSDO
< LOGICAL :: LCSD
```

For the new key LRITO , used in accvud, see further explanations concerning this routine.

Previously LNEBINS was hardly coded inside the accvud and acupu routines.

LNEBINS : with the old setting (T), the convective cloud fraction passed to aplmini from accvud and used in acupu for estimating the equivalent cloud fraction for microphysics, was estimated as $N_c = \Delta\sigma_D + \sigma_u$, where $\Delta\sigma_D$ is the increment of the detrainment fraction at current time step.

With the new setting (F), the complete detrainment area is more logically still considered as part of N_c i.e. $N_c = \sigma_D + \sigma_u$ (though only the increment condensate is considered).

It is advisable to remove the code associated with the old setting, which would allow to get rid of the additional array zdetfi ('detrainment fraction increment') in aplpar.

yomphy0

```
85a86
> !              ET DE LA CONSOMMATION CAPE (CONVECTION PROFONDE)
86a88
> !              AND CAPE CONSUMPTION (DEEP CONVECTION)
117,123d118
< !*NON SATURATED DOWNDRAFT
< !      GDDALBU : COEFF OF BUOYANCY ACCOUNTING FOR VARIOUS EFFECTS
< !      GDDFRAC : FRACTION OF PRECIPITATION AREA OCCUPIED BY DD
< !      GDDENDYMX: LIMITATION OF DYNAMICAL ENTRAIMENT IN DD
< !      GDDFP(1:2) : GAIN AND EXPONENT OF F(PRECIP) IN ACNSDO
< !      GDDPROM(1:2): GDDPROM(1)=MAX VALUE OF OMEGA_D
< !*
225d219
< !    QXRTAUIFR : TIME CONSTANT FOR ICE FRACTION IN XRCDEV
458,463d451
< REAL(KIND=JPRB) :: GDDALBU
< REAL(KIND=JPRB) :: GDDFRAC
< REAL(KIND=JPRB) :: GDDENDYMX
< REAL(KIND=JPRB) :: GDDFP(2)
< REAL(KIND=JPRB) :: GDDPROM(2)
495d482
< REAL(KIND=JPRB) :: QXRTAUIFR
619a609
> REAL (KIND=JPRB) :: GFRIC
```

Besides the specific parameters for the non-saturated downdraught a new parameter was introduced, **QXRTAUIFR** in order to make a distinction between the time constant used in the adjustment of liquid water and ice and the time scale GCVTAUDE used in the conversion of the detrained condensate into stratiform cloudiness.

su0phy

```
9,10c9,10
<  & LCAPE    ,LCVGQD   ,LCVGQM  ,LCONDWT  ,LCVPP  ,LCVDD  ,LHUNEG   ,&
<  & LNEIGE   ,LRNUMX   ,LCLSATUR,L2PHYS    ,LCVRA    , LGWD     ,&
---
>  & LCAPE    ,LCVGQD   ,LCVGQM  ,LCONDWT  ,LCVPP    ,LCVDD    ,LHUNEG   ,&
>  & LNEIGE   ,LRNUMX   ,LCLSATUR,L2PHYS    ,LCVRA    ,LGWD     ,&
33,35c33
<  & LDIFCEXP ,LSQRML   ,LNCVPGY  ,L2MICRO,&
<  & LRITO, LNSDO, LCSD ,&
<  & LNEBINS
---
>  & LDIFCEXP ,LSQRML   ,LNCVPGY  ,L2MICRO
417,423d414
< LNEBINS=.FALSE.
< ! ---------------------------------------------------
< ! ALARO-1 (prognostic convection)
< ! ---------------------------------------------------
< LRITO=.FALSE.
```

```
< LNSDO=.FALSE.
< LCSD=.FALSE.
981c972
< ! TESTS FOR ALARO-0 AND ALARO-1 (prognostic convection)
---
> ! TESTS FOR ALARO-0 (prognostic convection)
990d980
<
1058c1048,1049
<  & " LCOEFKTKE= ",L5," LCOEFK_QNSE= ",L5," LAFGD_A= ",L5  )')&
---
>  & " LCOEFKTKE= ",L5," LCOEFK_QNSE= ",L5," LAFGD_A= ",L5 &
>  & )')&
1133,1136c1124
< WRITE(UNIT=KULOUT,FMT='(" ALARO-1 prognostic convection  ")')
< WRITE(KULOUT,'("LNEBINS=",(L1,1X) )') LNEBINS
< WRITE(KULOUT,'(" LCSD=",L1, " LNSDO=",L1, " LRITO=",L1 )') &
<    & LCSD, LNSDO, LRITO
---
>
```

suphy0

```
126c126
<  & LNSDO  ,LPROCLD  ,LNEBCO   ,LNEBR    ,LECT     ,LNEBGR   ,LCVRAV3 ,L3MT ,&
---
>  & LPROCLD  ,LNEBCO   ,LNEBR    ,LECT     ,LNEBGR   ,LCVRAV3 ,L3MT ,&
136c136
<  & QXRAL    ,QXRDEL   ,QXRR     ,QXRTAUIFR,REVGSL   ,RTCAPE   ,SCO      ,&
---
>  & QXRAL    ,QXRDEL   ,QXRR     ,REVGSL   ,RTCAPE   ,SCO      ,&
164c164
<  & GCVBEE   ,GCVEEX   ,GCVTAUDE ,ECMNPI   ,&
---
>  & GCVBEE   ,GCVEEX   ,GCVTAUDE ,ECMNPI   ,GFRIC    ,&
175,177c175
<  & ECTMAX ,&
<  & GDDALBU  ,GDDENDYMX ,GDDFP    ,GDDFRAC  ,GDDPROM
<
---
>  & ECTMAX
260d257
< QXRTAUIFR=1800._JPRB
393a391
> GFRIC=-1.0_JPRB
411,419d408
< ! For non saturated downdraft
< GDDALBU=1._JPIM
< GDDFRAC=0.33_JPIM
< GDDENDYMX=1.E-4_JPRB
< GDDFP(1)=4.398E-2_JPRB
< GDDFP(2)=0.75_JPRB
< !
< GDDPROM(1)=180._JPRB   ! Pa/s
< GDDPROM(2)=0.02_JPRB   ! domd/dp [s^-1]
612d600
<  & ," QXRTAUIFR =",E11.4,/&
621,622c609
<  & ,QXRDEL,QXRHX,QXRR,QXRTGH,QXRTAUIFR &
<  & ,GWDLT,AHCLPV,GCVADS,GCVBETA,RICRLM,XBLM,XKLM,XMINLM &
---
>  &
,QXRDEL,QXRHX,QXRR,QXRTGH,GWDLT,AHCLPV,GCVADS,GCVBETA,RICRLM,XBLM,XKLM,XMINLM &
758a746
```

```
>  &," GFRIC =",G10.4 &
768c756
<  &  ECMNPI,&
---
>  &  ECMNPI,GFRIC,&
775,779d762
<  &'(" GDDALBU = ",G9.3," GDDFRAC= ",G9.3," GDDENDYMX =",G9.3,&
<  &" GDDFP=",2(1X,G9.3))')&
<  & GDDALBU, GDDFRAC, GDDENDYMX, GDDFP
<
< WRITE(KULOUT,&
```

namphy

```
6,8c6,7
<   &,LCAPE,LCVGQD,LCVGQM,LCONDWT,LCVCAS,LCVDD,LCVLIS,&
<   & LCVPP,LHUNEG,LNEIGE &
<   &,LRNUMX,LCLSATUR,L2PHYS,LRRGUST,LO3ABC,LO3FL,LECSHAL,LECDEEP,LNEBNXR,LNEBINS &
---
>   &,LCAPE,LCVGQD,LCVGQM,LCONDWT,LCVCAS,LCVDD,LCVLIS,LCVPP,LHUNEG,LNEIGE &
>   &,LRNUMX,LCLSATUR,L2PHYS,LRRGUST,LO3ABC,LO3FL,LECSHAL,LECDEEP,LNEBNXR &
13,14c12
<   &,LZ0HSREL,LCVPRO,LRITO,LCDDPRO,LNSDO,LCSD &
<   &,LENTCH,LCDDEVPRO &
---
>   &,LZ0HSREL,LCVPRO,LCDDPRO,LENTCH,LCDDEVPRO &
15a14
>
```

namphy0

```
9c9
<   &,QXRAL,QXRDEL,QXRHX,QXRR,QXRTGH,QXRTAUIFR,WMXOV,RPHI0,RPHIR &
---
>   &,QXRAL,QXRDEL,QXRHX,QXRR,QXRTGH,WMXOV,RPHI0,RPHIR &
28c28
<   &,GENVSRH,GRRINTE,GRRMINA,GDDBETA,GDDEVF,GDDWPF,GDDDP &
---
>   &,GENVSRH,GFRIC,GRRINTE,GRRMINA,GDDBETA,GDDEVF,GDDWPF,GDDDP &
45,47c45
<   &,RLMLH1,RLMLH2,RLMLH3,RPRTH,RFLCHCE &
< ! For sub grid updraft (ACCSU) and no saturated (ACCNSDO) schemes
<   &,GDDALBU,GDDENDYMX,GDDFP,GDDFRAC, GDDPROM
---
>   &,RLMLH1,RLMLH2,RLMLH3,RPRTH,RFLCHCE
```

The updating routines after the draughts parameterization were modified for including specific options under new keys, few corrections and coding changes.

acupu

The main modification concerns the change of equivalent cloudiness computation. The impact is quite important as shown in section 5.

```
9c9
< ! - OUTPUT 1D .
---
> ! - OUTPUT  1D .
89d88
< USE YOMPHY   , ONLY : LNEBINS
127d125
< REAL(KIND=JPRB), PARAMETER :: ZEPS0=1.E-12_JPRB
129a128
> LOGICAL :: LLNEBINS
```

```
134,135c133,134
< REAL (KIND=JPRB) :: ZPX(KLON),ZCC1(KLON),ZCS1(KLON),ZNEBC(KLON),ZUDAL(KLON)
< REAL(KIND=JPRB)  :: ZFRCO, ZNEI,ZNEQ,&
---
> REAL (KIND=JPRB) :: ZPX(KLON), ZCC1(KLON), ZCS1(KLON)
> REAL(KIND=JPRB)  :: ZEPS0, ZFRCO, ZNEBC,ZNEI,ZNEQ,&
147a147
> ZEPS0=1.E-12_JPRB
148a149
> LLNEBINS=.FALSE.
207d207
<   ZUDAL(:)=MAX(0._JPRB,PUDAL(:,JLEV))
214c214
<    ZZ=MAX(0.0_JPRB, 1.0_JPRB-ZUDAL(JLON))
---
>     ZZ=MAX(0.0_JPRB, 1.0_JPRB-PUDAL(JLON,JLEV))
216c216
<    PSIGP(JLON)=MIN(PSIGP(JLON),ZZ)
---
>     PSIGP(JLON)=MIN(PSIGP(JLON),ZZ)
218,219c218,220
<    IF (LNEBINS) THEN
<       ZNEBC(JLON)=PDETFI(JLON,JLEV)+ZUDAL(JLON)
---
>
>    IF (LLNEBINS) THEN
>      ZNEBC=PDETFI(JLON,JLEV)+PUDAL(JLON,JLEV)
221c222
<       ZNEBC(JLON)=PUNEBH(JLON,JLEV)+ZUDAL(JLON)
---
>      ZNEBC=PUNEBH(JLON,JLEV)+PUDAL(JLON,JLEV)
233c234
<         & *MAX(0.0_JPRB,SIGN(1.0_JPRB,ZNEBC(JLON)-GRRMINA))
---
>         & *MAX(0.0_JPRB,SIGN(1.0_JPRB,ZNEBC-GRRMINA))
236,240c237,238
< !    ESTIMATE OF STRATIFORM FRACTION: (1-n_c)*PNEBE
< !    -------------------------------
< ! THIS ENSURES THAT THEIR SUM IS THE (UPDATED) TOTAL CLOUDINESS <=1
<       PNEBE(JLON,JLEV)=PNEBE(JLON,JLEV)*(1._JPRB-ZNEBC(JLON))
<       ZPX(JLON)=MAX(ZPX(JLON),PNEBE(JLON,JLEV))
---
>
> !    COMPUTE REDUCED CLOUD FRACTIONS
241a240,255
> ! such that their sum is the (updated) total cloudiness
> !--------------
> ! nc+ns
>       ZZ1=ZNEBC+PNEBE(JLON,JLEV)
> ! n_tot=nc+ns-nc*ns
>       ZZ2=ZZ1-ZNEBC*PNEBE(JLON,JLEV)
> ! STORE THE MAXIMUM CLOUD and MIN ud envt OVER VERTICAL
>       ZPX(JLON)=MAX(ZPX(JLON),ZZ2)
>
>       ZZ=MAX(0.0_JPRB,SIGN(1.0_JPRB,ZZ1-GRRMINA))
> ! nc'=nc*ntot/(nc+ns)  or zero if (nc+ns)<1E-5
>       ZNEBC=ZZ*ZNEBC*ZZ2/(ZZ1+(1.0_JPRB-ZZ))
> ! ns'=ns*ntot/(nc+ns)  or zero if (nc+ns)<1E-5
>       PNEBE(JLON,JLEV)=ZZ*PNEBE(JLON,JLEV)*ZZ2/(ZZ1+(1.0_JPRB-ZZ))
>
> !--------------
248c262
<       ZZ2=MAX(0.0_JPRB,SIGN(1.0_JPRB,ZNEBC(JLON)-GRRMINA))
---
>       ZZ2=MAX(0.0_JPRB,SIGN(1.0_JPRB,ZNEBC-GRRMINA))
```

```
251c265
<          &+ZZ2*(1.0_JPRB-ZZ1)*ZNEBC(JLON)
---
>          &+ZZ2*(1.0_JPRB-ZZ1)*ZNEBC
256c270
<          &+ZFRCO*ZFRCO/(ZNEBC(JLON)+(1.0_JPRB-ZZ2))
---
>          &+ZFRCO*ZFRCO/(ZNEBC+(1.0_JPRB-ZZ2))
```

acupm

```
41c41
< ! PEVEL0    : RESOLVED VERTICAL VELOCITY (omega)
---
> ! PEVEL0    : ETA_dot*d(Pi)/d(ETA)at full levels
100c100
< USE YOMPHY   , ONLY : LCDDEVPRO, LNSDO
---
> USE YOMPHY   , ONLY : LCDDEVPRO
148c148
< REAL(KIND=JPRB)  :: ZDDEVC, ZDEVPL, ZDEVPN, ZQX1, ZDQR, ZDQS, ZDQC,&
---
> REAL(KIND=JPRB)  :: ZDDEVC,  ZUDAL, ZQX1, ZDQR, ZDQS, ZDQC,&
166,169c166,167
< ELSE IF (LNSDO) THEN
<   ZDDEVC=1._JPRB
< ELSE
<   ZDDEVC=0._JPRB
---
> ELSE
>   ZDDEVC=0.0_JPRB
254,255d251
<     ZDEVPL=PFPEVPSL(JLON,JLEV)-PFPEVPSL(JLON,JLEV-1)
<     ZDEVPN=PFPEVPSN(JLON,JLEV)-PFPEVPSN(JLON,JLEV-1)
257c253,254
<      &  PLHV(JLON,JLEV)*ZDEVPL +PLHS(JLON,JLEV)*ZDEVPN )
---
>      &  PLHV(JLON,JLEV)*(PFPEVPSL(JLON,JLEV)-PFPEVPSL(JLON,JLEV-1)) &
>      & +PLHS(JLON,JLEV)*(PFPEVPSN(JLON,JLEV)-PFPEVPSN(JLON,JLEV-1)) )
262,263d258
<     IF (LNSDO) &
<      & PZQV(JLON,JLEV)=PZQV(JLON,JLEV)+ZDDEVC*PIPOI(JLON,JLEV)*(ZDEVPL+ZDEVPN)
265a261
>     ! according to LUDEN switch
267c263,264
< ! Mean Updraught environment vertical velocity: FOR ACMODO ONLY
---
>     ZUDAL=MIN(GCVALMX,PUDAL(JLON,JLEV))
> ! Mean Updraught environment vertical velocity:
269c266
<        &   -MIN(GCVALMX,PUDAL(JLON,JLEV)*PUDOM(JLON,JLEV)) )*TSPHY
---
>        &   -ZUDAL*PUDOM(JLON,JLEV))*TSPHY
```

acupd

```
93c93
< USE YOMPHY   , ONLY : LCDDEVPRO, LENTCH, LNSDO
---
> USE YOMPHY   , ONLY : LCDDEVPRO, LENTCH
170,171d169
< ELSE IF (LNSDO) THEN
<   ZPHCLOS=0._JPRB
229d226
< ! PREVENT NEGATIVE SNOW
```

```
230a228
>
242,246d239
< ! PREVENT NEGATIVE RAIN
<     ZCOR=MIN(0._JPRB,PFPLSL(JLON,JLEV))
<     PFPLSL(JLON,JLEV)=PFPLSL(JLON,JLEV)-ZCOR
<     PFPEVPCL(JLON,JLEV)=PFPEVPCL(JLON,JLEV)+ZCOR/ZSTAL3(JLON)
<
315c308
<         & - PLHV(JLON,JLEV)*ZDEVQR-PLHS(JLON,JLEV)*ZDEVQS )/PCP(JLON,JLEV)
---
➢        & + PLHV(JLON,JLEV)*ZDEVQR+PLHS(JLON,JLEV)*ZDEVQS )/PCP(JLON,JLEV)
➢
```

accvud

In accvud, LRITO controls the limitation of the updraught top to the highest level that can be reached in current time step seen the value of the updraught vertical velocity.

* If LRITO=T:

zsum accumulates the ratio dp/(-omega_u*dt) at levels that are buoyant (inbu=1) but were not yet active when entering the routine (indet=0).

when zsum>1 it means that the level cannot be reached, and we set knact=0 (unless we are at the base of the ascent).

* if LRITO=F:

we set knact=inbu, i.e. all buoyant levels are set active.

* In both cases, the ascent base indicator (inbas=1) is set as inbu(l)*(1-inbu(l+1))

Difference with the reference:

```
7a8
>               &PDDAL,&
69a71
> ! PDDAL      : Prognostic downdraught mesh fraction (case LENTCH)
125c127
< ! PUDOM    : PROGNOSTIC UPDRAUGHT RELATIVE VELOCITY
---
> ! PUDOM    : PROGNOSTIC UPDRAUGHT RELATIVE VELOCITY
166,167c168,169
< USE YOMPHY   , ONLY : NBITER   ,NPHYREP  ,LNEBINS , &
<           &LCAPE, LSLC, LNOIAS, LSCMF, LENTCH, LCVGQM, LRITO, NIMELIT
---
> USE YOMPHY   , ONLY : NBITER   ,NPHYREP  ,LCVDD    ,&
>           &LCAPE, LSLC, LNOIAS, LSCMF,LENTCH,LCDDPRO,LCVGQM,NIMELIT
174c176
<           &TUDGP    ,GCVADS  ,&
---
>           &TUDGP    ,USDMLT   ,GCVADS  ,GCVBETA  ,&
177c179,181
<           &GCVBEE   ,GCVTAUDE ,GENVSRH ,ECMNPI
---
>           &GCVBEE   ,GCVTAUDE ,GENVSRH ,&
>           &ECMNPI   ,GPEIPHI  ,GPETAU  ,GPEFDC   ,&
>           &SENTR    ,SENTRX   ,NPEEXP0 ,NPEEXP1
212a217
> REAL(KIND=JPRB)   ,INTENT(IN)    :: PDDAL(KLON,KLEV)
314c319
< LOGICAL :: LLLCL, LLDIVENT, LLDEQC, LLCOLDS
---
> LOGICAL :: LLLCL, LLDIVENT, LLDEQC, LLNEBINS, LLCOLDS
333a339
> LLNEBINS=.FALSE.
502c508
< ! PUDOM : ADVECTED RELATIVE UD VELOCITY
```

```
---
> ! PUDOM : ADVECTED RELATIVE UD VELOCITY SET TO RELATIVE UD VELOCITY*DT
1037a1044,1045
>     INDET(JLON,KLEV)=INDET(JLON,KLEV)*INBU(JLON,KLEV)
>     KNACT(JLON,KLEV)=INBU(JLON,KLEV)
1039,1061c1047,1058
<   IF (LRITO) THEN
<     ZSUM=0.0_JPRB
<     KNACT(KIDIA:KFDIA,KLEV)=INBU(KIDIA:KFDIA,KLEV)
<     DO JLEV=KLEV-1, ITOP, -1
<       DO JLON=KIDIA,KFDIA
<         INBAS(JLON,JLEV)=IOLD*INBU(JLON,JLEV)*(1-INBU(JLON,JLEV+1))
<         INDET(JLON,JLEV)=INDET(JLON,JLEV)*INBU(JLON,JLEV)
<         ITRAN=1-INDET(JLON,JLEV)
<         ZSUM(JLON)=INBU(JLON,JLEV)*(ZSUM(JLON)-ITRAN*PDELP(JLON,JLEV)&
<           & /MIN(ZEPSDOM0,PUDOM(JLON,JLEV)))
<         ITRAN=ITRAN*(1-INBAS(JLON,JLEV))* &
<          & MAX(0.0_JPRB,SIGN(1.0_JPRB,ZSUM(JLON)-1.0_JPRB))
<         KNACT(JLON,JLEV)=INBU(JLON,JLEV)*(1-ITRAN)
< ! NOW STORE minus THE UPDRAUGHT VELOCITY AT THE HALF LEVEL IN ZFORM
<         ZFORM(JLON,JLEV)=-INBU(JLON,JLEV)*0.5_JPRB*&
<           & (PUDOM(JLON,JLEV)+PUDOM(JLON,JLEV+1))
<       ENDDO
<     ENDDO
<   ELSE
<     KNACT(KIDIA:KFDIA,ITOP:KLEV)=INBU(KIDIA:KFDIA,ITOP:KLEV)
<     DO JLEV=KLEV-1, ITOP, -1
<       DO JLON=KIDIA,KFDIA
<         INBAS(JLON,JLEV)=IOLD*INBU(JLON,JLEV)*(1-INBU(JLON,JLEV+1))
---
>   ZSUM=0.0_JPRB
>   DO JLEV=KLEV-1,ITOP,-1
>     DO JLON=KIDIA,KFDIA
>       INBAS(JLON,JLEV)=IOLD*INBU(JLON,JLEV)*(1-INBU(JLON,JLEV+1))
>       INDET(JLON,JLEV)=INDET(JLON,JLEV)*INBU(JLON,JLEV)
>       ITRAN=1-INDET(JLON,JLEV)
>       ZSUM(JLON)=INBU(JLON,JLEV)*(ZSUM(JLON)-ITRAN*PDELP(JLON,JLEV)&
>         & /MIN(ZEPSDOM0,PUDOM(JLON,JLEV)))
>       ITRAN=ITRAN*(1-INBAS(JLON,JLEV))* &
>         & MAX(0.0_JPRB,SIGN(1.0_JPRB,ZSUM(JLON)-1.0_JPRB))
>       KNACT(JLON,JLEV)=INBU(JLON,JLEV)*(1-ITRAN)
>
1063,1067d1059
<         ZFORM(JLON,JLEV)=-INBU(JLON,JLEV)*0.5_JPRB*&
<           & (PUDOM(JLON,JLEV)+PUDOM(JLON,JLEV+1))
<       ENDDO
<     ENDDO
<   ENDIF
1069c1061,1065
< ! Level KLEV:
---
>       ZFORM(JLON,JLEV)=-INBU(JLON,JLEV)*0.5_JPRB*&
>         & (PUDOM(JLON,JLEV)+PUDOM(JLON,JLEV+1))
>     ENDDO
>   ENDDO
>
1213a1210
>       INBU(JLON,JLEV)=KNND(JLON)*INBU(JLON,JLEV)
1284a1282
>       INBU(JLON,JLEV)=INBU(JLON,JLEV)*KNND(JLON)
1420c1418
<     & *ZMELNET(JLON,ITOP)*INBU(JLON,ITOP)
---
>     & *ZMELNET(JLON,ITOP)*KNACT(JLON,ITOP)
1437c1435
```

```
<       & *ZMELNET(JLON,JLEV)*INBU(JLON,JLEV)
---
>       & *ZMELNET(JLON,JLEV)*KNACT(JLON,JLEV)
1452c1450
<     & *ZMELNET(JLON,KLEV)*INBU(JLON,KLEV)
---
>     & *ZMELNET(JLON,KLEV)*KNACT(JLON,KLEV)
1463a1462,1491
>
> ! OLD CODE
> ! Contribution of divergence of mass flux to updraught condensate budget.
>
> !   DO JLON=KIDIA,KFDIA
> !     ZAUX=1.0_JPRB/(PDELP(JLON,ITOP)+ZFORM(JLON,ITOP))
> !     ZFMDQC(JLON)=ZFORM(JLON,ITOP) &
> !    & *(ZLDN(JLON,ITOP)+ZLDN(JLON,ITOP+1))*0.5_JPRB
> !     ZCR(JLON)=ZAUX*ZFMDQC(JLON)
> !     ZDEQCA(JLON,ITOP)=ZDEQCA(JLON,ITOP)-ZCR(JLON)
> !   ENDDO
> !   !cdir unroll=8
> !   DO JLEV=ITOP+1,KLEV-1
> !     DO JLON=KIDIA,KFDIA
> !       ZAUX=1.0_JPRB/(PDELP(JLON,JLEV)+ZFORM(JLON,JLEV))
> !       ZFMDQCL=ZFORM(JLON,JLEV) &
> !      & *(ZLDN(JLON,JLEV)+ZLDN(JLON,JLEV+1))*0.5_JPRB
> !       ZCR(JLON)=ZAUX*(ZFMDQC(JLON)-ZFMDQCL+ZCR(JLON)*ZFORM(JLON,JLEV-1))
> !       ZFMDQC(JLON)=ZFMDQCL
> !       ZDEQCA(JLON,JLEV)=ZDEQCA(JLON,JLEV)-ZCR(JLON)
> !     ENDDO
> !   ENDDO
> !   DO JLON=KIDIA,KFDIA
> !     ZAUX=1.0_JPRB/(PDELP(JLON,KLEV)+ZFORM(JLON,KLEV))
> !     ZFMDQCL=ZFORM(JLON,KLEV)*ZLDN(JLON,KLEV)*0.5_JPRB
> !     ZCR(JLON)=ZAUX*(ZFMDQC(JLON)+ZFMDQCL+ZCR(JLON)*ZFORM(JLON,KLEV-1))
> !     ZFMDQC(JLON)=ZFMDQCL
> !     ZDEQCA(JLON,KLEV)=ZDEQCA(JLON,KLEV)-ZCR(JLON)
> !   ENDDO
>
1475,1476c1503,1504
<       ENDDO
<     ENDDO
---
>       ENDDO
>     ENDDO
1480a1509
>
1482c1511
<         ZENTR=ZENT(JLON,JLEV)*ZFF*PRDELP(JLON,JLEV)
---
>       ZENTR=ZENT(JLON,JLEV)*ZFF*PRDELP(JLON,JLEV)
1487a1517,1518
>         PFRDE(JLON,JLEV)=ZFRDE(JLON,JLEV)*ZEXPND+&
>               & ZZ3* ZDEQC/(ZLDN(JLON,JLEV)+(1.0_JPRB-ZZ3))*KNND(JLON)
1494a1526
>
1498c1530,1533
<   ELSE  ! Detrainment BY MASS BUDGET **inadequate here**
---
>   ELSE  ! Detrainement BY MASS BUDGET
>
>     ZCR(:)=0.0_JPRB
>
1505c1540
< ! Mass entrainment (inadequate)
---
```

```
> ! Mass entrainment
1509a1545
>         PFRDE(JLON,JLEV)=ZFRDE(JLON,JLEV)*ZEXPND+ZDEQC*KNND(JLON)
1510a1547,1548
>         ZCR(JLON)=ZFF
>
1512,1515c1550,1557
<         ZZ=ZFRDE(JLON,JLEV)*ZEXPND+PDETFI(JLON,JLEV)
<         PFRDE(JLON,JLEV)=MIN(1.0_JPRB-PUDAL(JLON,JLEV),ZZ)
<         PDETFI(JLON,JLEV)=MAX(0.0_JPRB,PDETFI(JLON,JLEV)&
<                            & -(ZZ-PFRDE(JLON,JLEV)))
---
>         ZZ2=MAX(0.0_JPRB, SIGN(1.0_JPRB,PFRDE(JLON,JLEV)-ZEPSALDE))
>         PFRDE(JLON,JLEV)=MIN(1.0_JPRB-PUDAL(JLON,JLEV),&
>                      &PFRDE(JLON,JLEV)*ZZ2)
>         ZZ2=MAX(0.0_JPRB, SIGN(1.0_JPRB,PDETFI(JLON,JLEV)-ZEPSALDE))
>         PDETFI(JLON,JLEV)=MIN(1.0_JPRB-PUDAL(JLON,JLEV),&
>                      &PDETFI(JLON,JLEV)*ZZ2)
>
>
1532c1574
<       IF(LNEBINS) THEN
---
>       IF(LLNEBINS) THEN
1558,1559c1600,1601
<          &*INBU(JLON,JLEV))
<         ZSUM2(JLON)=ZSUM2(JLON)+(ZLHCORR(JLON,JLEV)*INBU(JLON,JLEV))
---
>          &*KNACT(JLON,JLEV))
>         ZSUM2(JLON)=ZSUM2(JLON)+(ZLHCORR(JLON,JLEV)*KNACT(JLON,JLEV))
1675a1718,1722
> ! DO JLEV=KTDIA,KLEV
> !   DO JLON=KIDIA,KFDIA
> !     PFRDE(JLON,JLEV)=0.0_JPRB
> !   ENDDO
> ! ENDDO
```

accdev

The parameter GCVTAUDE was replaced by a distinct one **QXRTAUIFR** (correction of an old quick fix, becoming inadequate if the value of GCVTAUDE is changed):

```
149c149
< USE YOMPHY0  , ONLY : RSMDTX, RDTFAC, QXRTAUIFR
---
> USE YOMPHY0  , ONLY : RSMDTX, RDTFAC, GCVTAUDE
253c253
< ZWEIGHT=1.0_JPRB-EXP(-TSPHY/QXRTAUIFR)
---
> ZWEIGHT=1.0_JPRB-EXP(-TSPHY/GCVTAUDE)
```

acnebcond

A minor modification: a line was deleted from a loop where ZMESH is not used

```
248a249
>       ZMESH=REFLRHC/(TEQH*PGM(JLON))
```

The modified routines (and as well the corresponding differences) can be found on yaga, ~mma155/sources/csd/csd_op8_DD.

5. Code validation and comparison with the reference

Several experiments were carried out for the 29th of June 2009 in order to validate the modifications and to assess the impact of the modifications:

For saturated downdraught:

t1p8 : LRITO=F**,** GCVTAUDE=900, QXRTAUIFR =900, LNSDO=F
with last corrections/modifications
uu18 : LRITO=F**,** GCVTAUDE=900, QXRTAUIFR =900, LNSDO=F, GDDEVF=0.
with last corrections/modifications

For non-saturated downdraught
md18 : LRITO=F, GCVTAUDE=900, QXRTAUIFR =900, LNSDO=T, LCSD=T,
without the correction of acupu for the equivalent cloudiness computation
md19 : LRITO=F, , QXRTAUIFR =900 LNSDO=T, LCSD=T, GCVTAUDE=900
without the correction of acupu for the equivalent cloudiness computation
mu18 : LRITO=F, GCVTAUDE=900, QXRTAUIFR =900, LNSDO=T, LCSD=T
GCVTAUDE=900
mu19 : LRITO=T, GCVTAUDE=900, QXRTAUIFR =900

The simulations results are compared with the reference - **oop8** for what the operational executable was used. As well it is presented the comparison with the best results obtained in December 2013 – **d818**, using ω_u and σ_u as advected variables (as the operational). The verification scores for 10 days (24th of June – 3rd of July 2009) using the setup of the d818 generally showed an improvement with respect to the reference (see figure 1)

As usually the diurnal cycle, cumulated precipitation and budgets are presented.

Objective verification: 21st June – 30th July2009

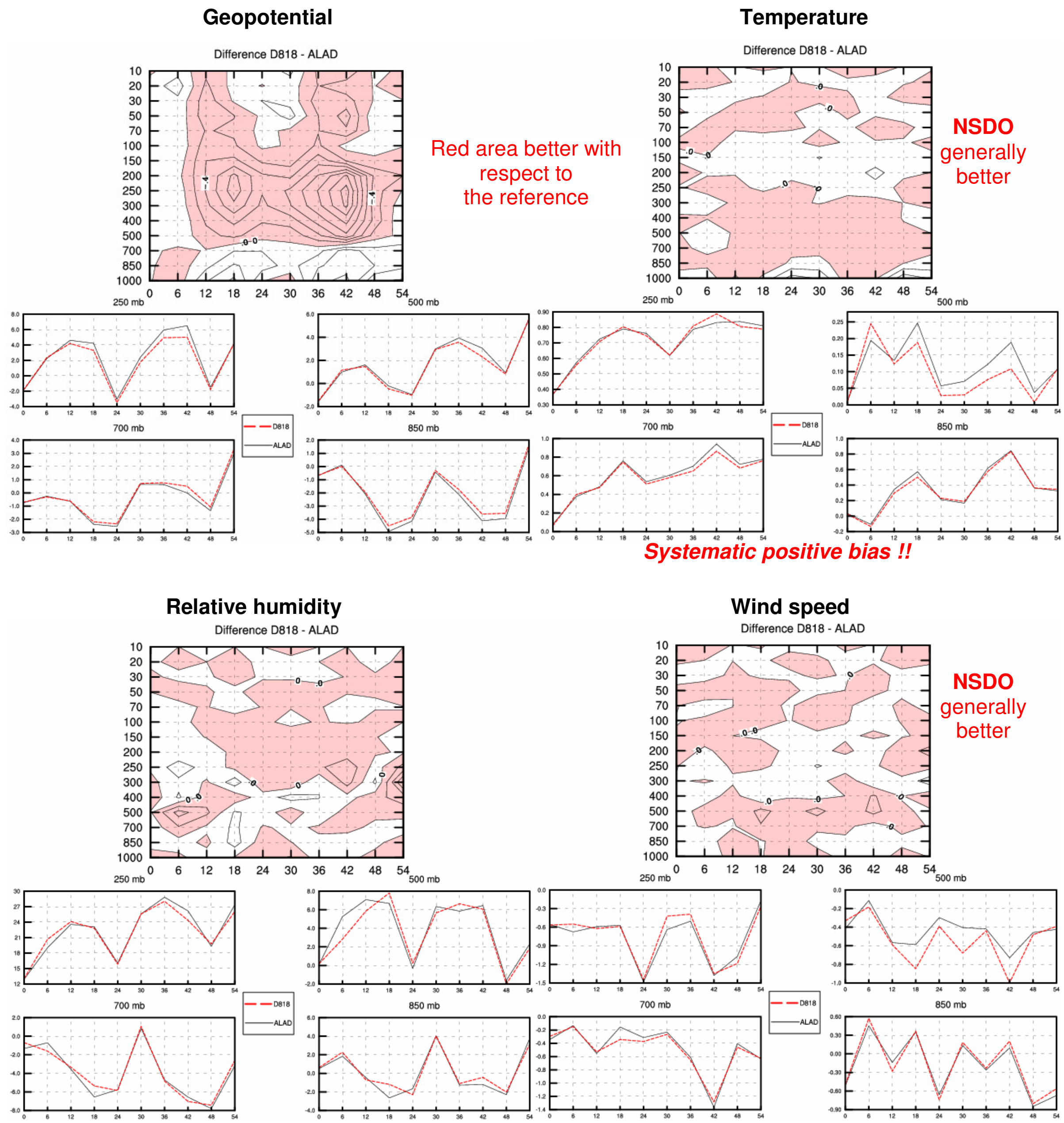


Fig. 1 Geopotential (top left),temperature (top=right), relative humidity (bottom –left) and wind speed (bottom- right) bias for 21st - 30th of June 2009

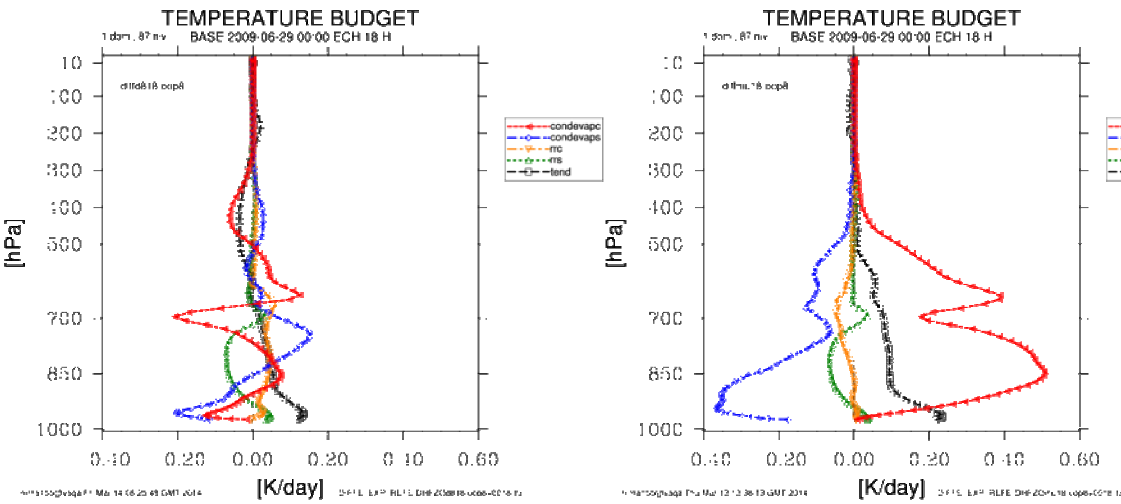


Fig. 2 Temperature budget difference (experiment – reference) for 29th of June 2009 18UTC: d818 (December 2013) – left, mu18 (LRITO=F, GCVTAUDE=900) – right

For the test carried out in December 2013 in Prague the budget differences in respect with the reference (oop8) show the temperature tendency increase between 1000- 600 hPa and a decrease in the layer 600-200 hPa. With the new code (same set up) the negative of the temperature tendency difference is diminished, while the positive one is enhanced over a thicker layer.

The temperature budget differences between the full run and with only updraught parameterization allow the evaluation of the saturated downdraught (operational) and respectively of the non saturated complementary sub-grid downdraught contribution.

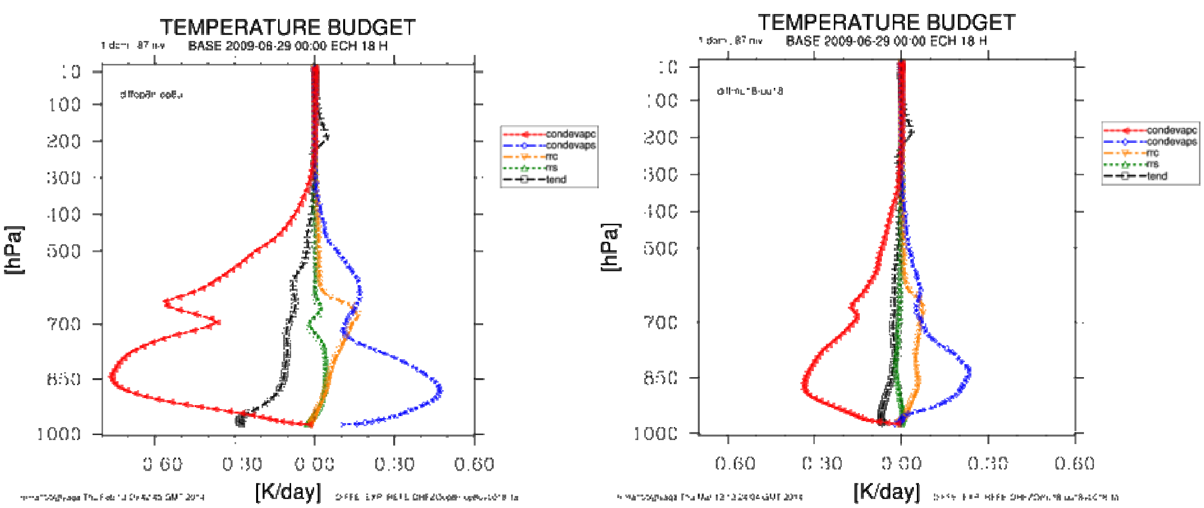


Fig. 3 Temperature budget difference (full run – only updraught parameterization) for 29th of June 2009 18UTC: saturated downdraught (operational) – left , non saturated complementary sub-grid downdraught – right.

The sub-grid non saturated downdraught contribution is significantly smaller in respect to the saturated downdraught. For instance the maximum temperature tendency variation is about 0.3 K/day for saturated downdraught while for non saturated one is about one third.

Since the correction of the equivalent cloud computation was an important one, its impact was separately evaluated: the temperature budget difference between the experiments with and without the correction is presented in figure 4.

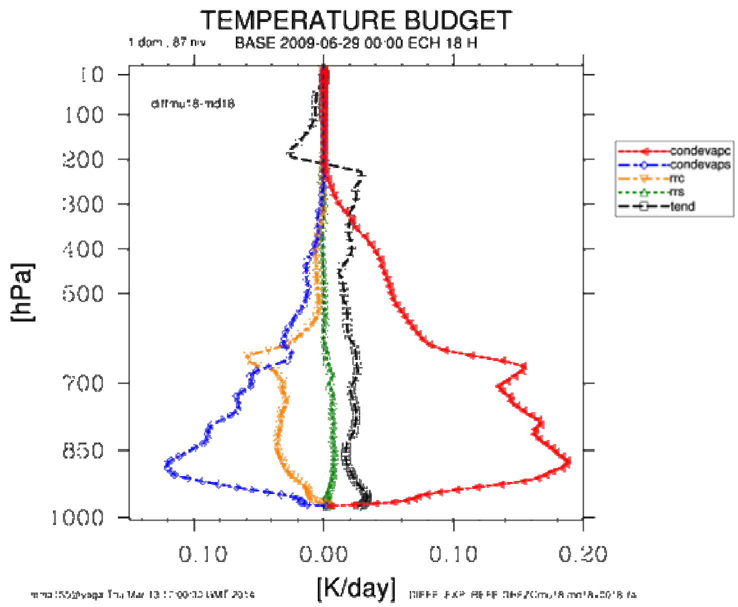


Fig. 4 Impact of the correction of acupu for the equivalent cloud computation: temperature budget difference between the experiment with (mu18) and without (md18) correction for 29th of June 2008 18UTC.

In fact the last corrections/modifications of the updraught and updating routines acupu, acupm, acupd have the same effect of a small increase of the temperature tendency when the saturated downdraught is activated. Obviously a re-tuning will be necessary (even for the case of using the saturated downdraught parameterization); it will be done when last modification of radiation and turbulence parameterizations will be included in Alaro-1.

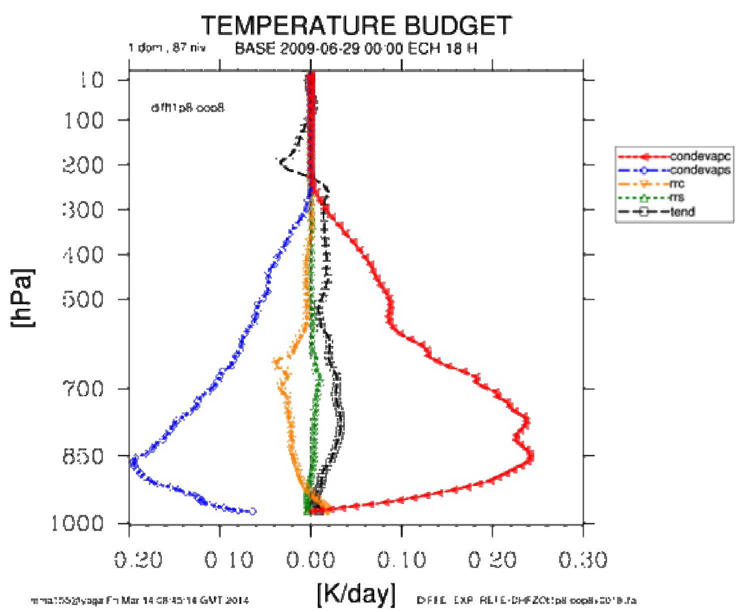


Fig. 5 Impact of the correction of the last modifications in the case of saturated downdraught : temperature budget difference between the experiment with the last modifications (t1p8) and the operational version (oop8) for 29th of June 2008 18UTC

The set up of LRITO=T has rather small impact on the temperature tendency; there are negative in the lower troposphere (below 850 hPa) and a positive one above.

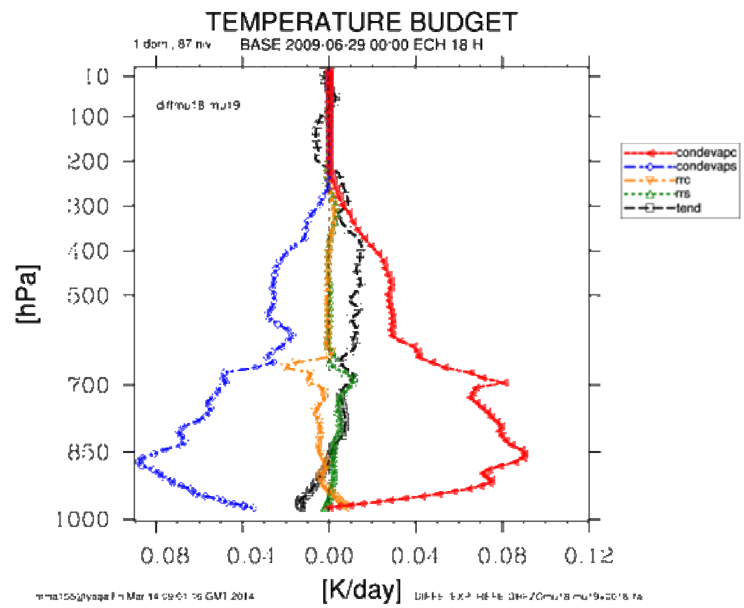


Fig. 6 Temperature budget difference between mu18 (LRITO=F)   and mu19 (LRITO=T): 29th of June 2009 18UTC

The modifications of the prognostic updraught (accvud) and updating routines affect very little the diurnal cycle (for 29th of June 2009) for the saturated downdraught. (fig. 7, blue lines). The impact, as well small, of the sole correction of acupu was evaluate only for the complementary sub-grid downdraught (fig. 7 red lines).

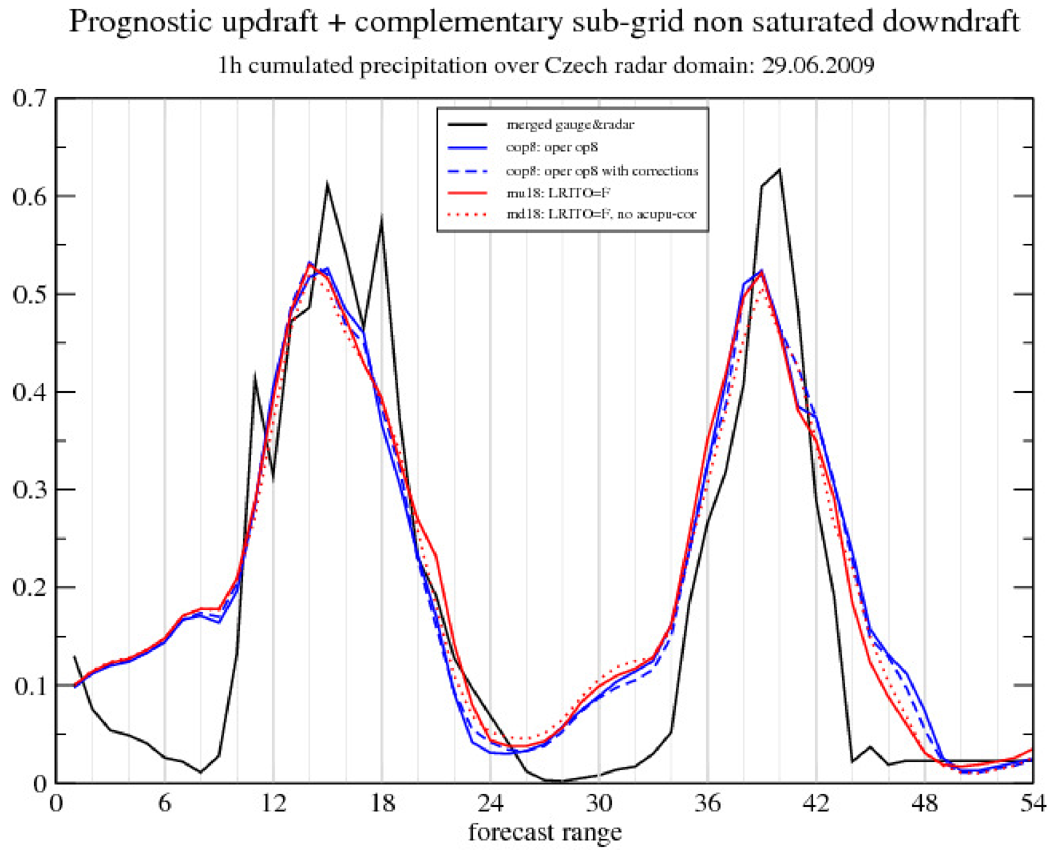


Fig. 7 Precipitation diurnal cycle over the Czech "radar domain" for 29[th] of June 2009 without the acupu correction: merged radar & gauges –black line, reference (oop8) – blue line, reference with modification of accvud, acupu, acupm, acupd (t1p8: LRITO=F, LNSDO=F) dashed blue line, unsaturated downdraught mu18 (LRITO=F) – red line and unsaturated downdraught without acupu correction (md18) – dot red line

The correction made in the computation of the equivalent cloudiness slightly improves the diurnal cycle.

The impact of LRITO on the diurnal cycle is presented in figure 8, in comparison with the precipitation evolution obtained in December 2013.

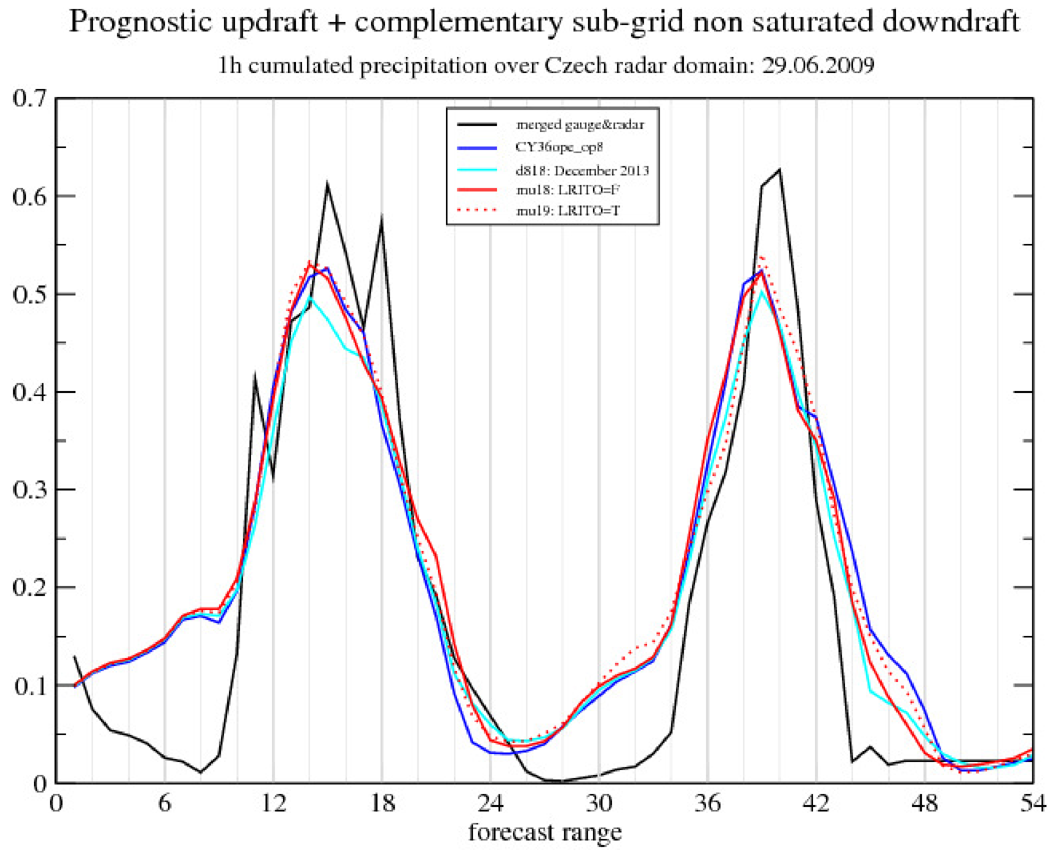


Fig. 8 Precipitation diurnal cycle over the Czech "radar domain" for 29th of June 2009: merged radar & gauges – black line, reference (oop8) – blue line, d818 (December 2013) – cyan line, mu18 (LRITO=F) – red line and mu19 (LRITO=T) – dot red line

Again the spatial distribution of 1 h and 6h (for which the differences are more visible) cumulated precipitation was analyzed. They are presented in figures 9 and 10.

The differences are quite small and concern the position of the most intense precipitation nuclei. The set up of LRITO=T diminishes a bit the values of these nuclei, especially in the absence of the acupu correction.

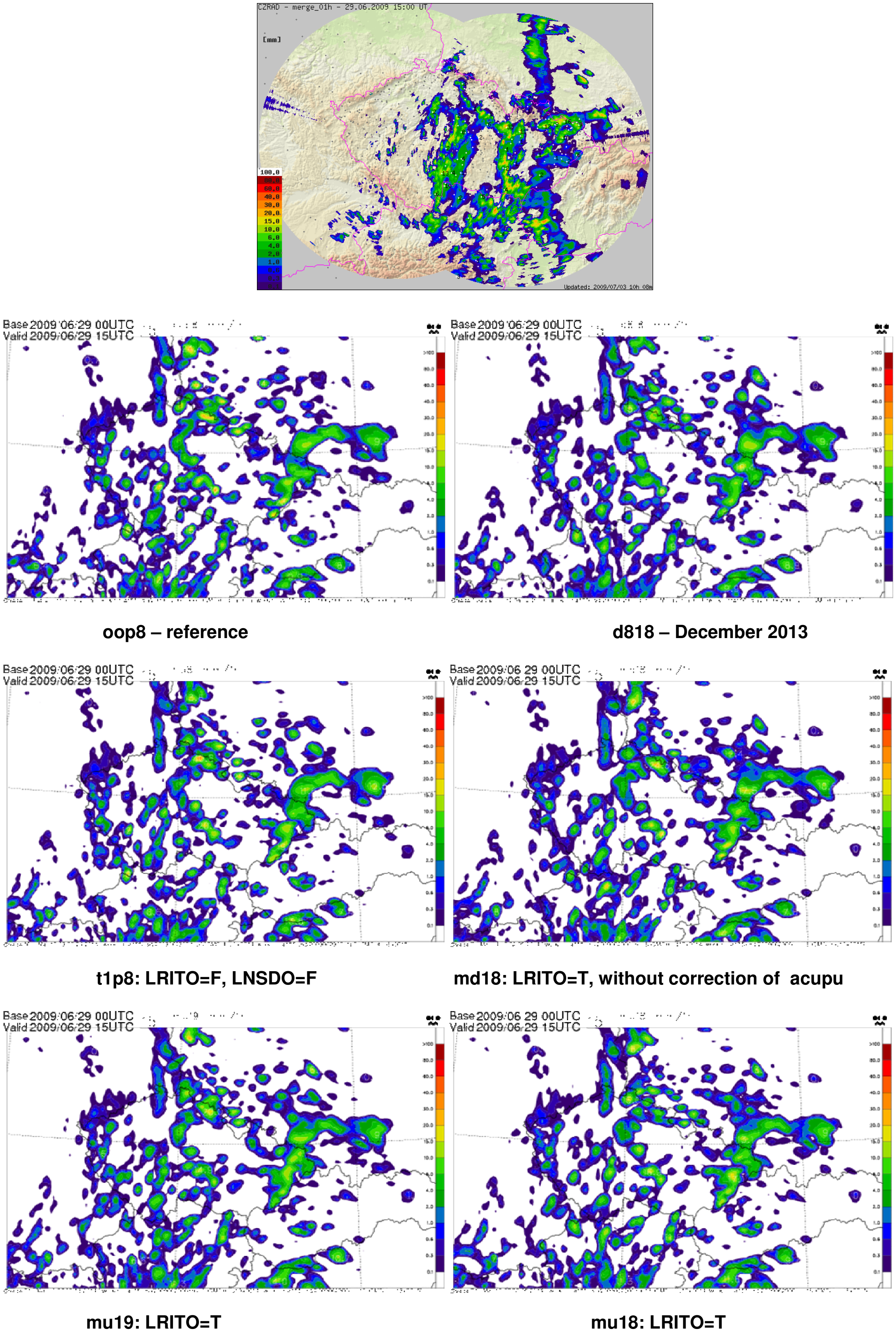
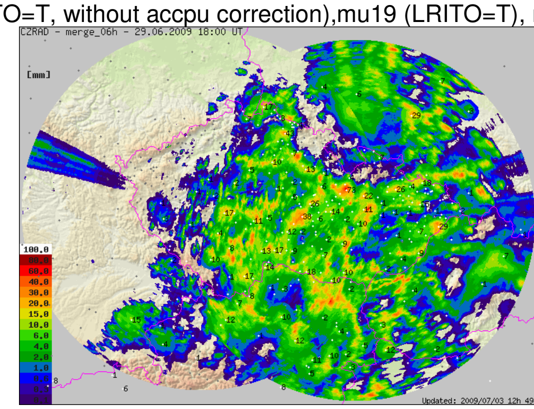
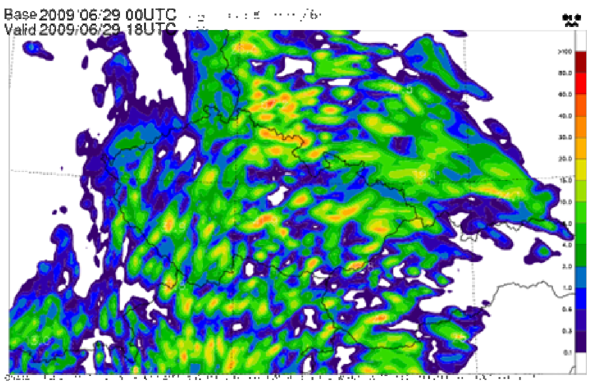


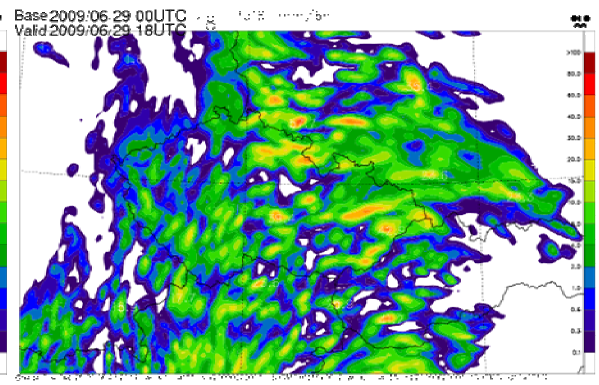
Fig. 9 1 h cumulated precipitation for 29th of June 2008 15UTC; radar – top and from top-down and left-right :

oop8 (reference), d818 (December 2013),
t1p8 (reference + accvud, acupu, acupm, acupd modifications, LRITO=F, LNSDO=F)
md18(LRITO=T, without accpu correction),mu19 (LRITO=T), mu18 (LRITO=F)

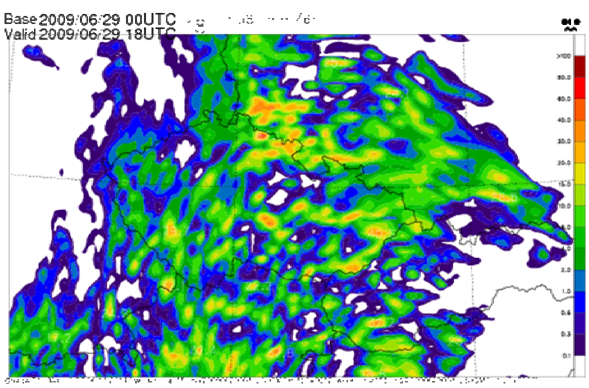




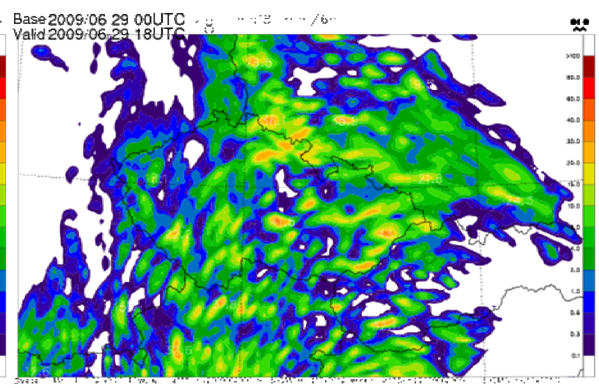
oop8 – reference



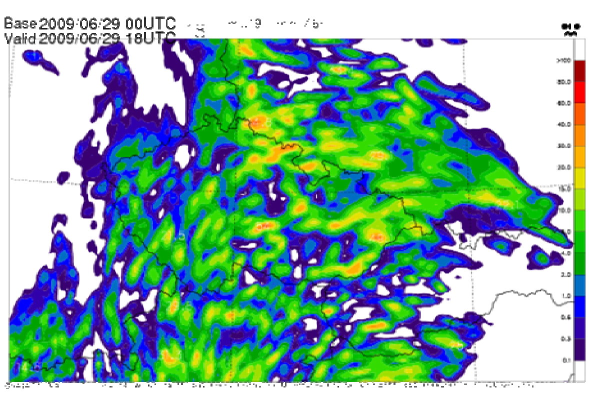
d818 – December 2013

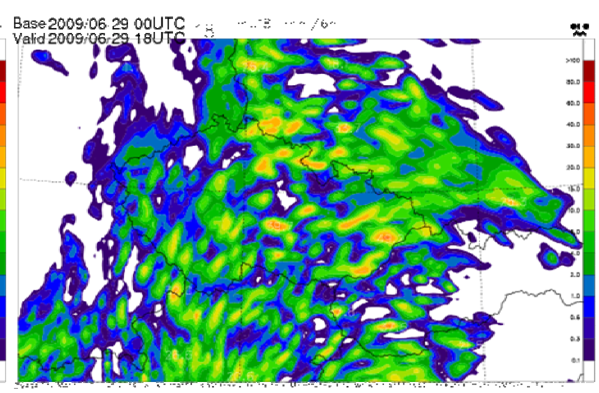


t1p8: LRITO=F, LNSDO=T



md18: LRITO=F, without correction of accpu





mu19: LRITO=T **mu18: LRITO=F**

Fig. 10 1 h cumulated precipitation for 29th of June 2008 15UTC; radar – top and from top-down and left-right : oop8 (reference), d818 (December 2013), t1p8 (reference + accvud, acupu, acupm, acupd modifications, LRITO=F, LNSDO=F) md18(LRITO=T, without accpu correction),mu19 (LRITO=T), mu18 (LRITO=F)

6. Non saturated downdraught tuning

6.1 Variation of the downdraught entrainment rate

In order to reduce the warming induced by the last modifications the downdraught entrainment rate was increased (trying to keep unchanged the up draught parameter set up). Indeed the effect of increasing the entrainment rate (from 0.5E-04 in the reference experiment, mu18 up to 1.E-04 in m004 and 2.E-04 in m005 experiment) is the cooling of the medium troposphere. But it is accompanied by an undesirable warming under 850 hPa and a thin layer between 200 -300 hPa.

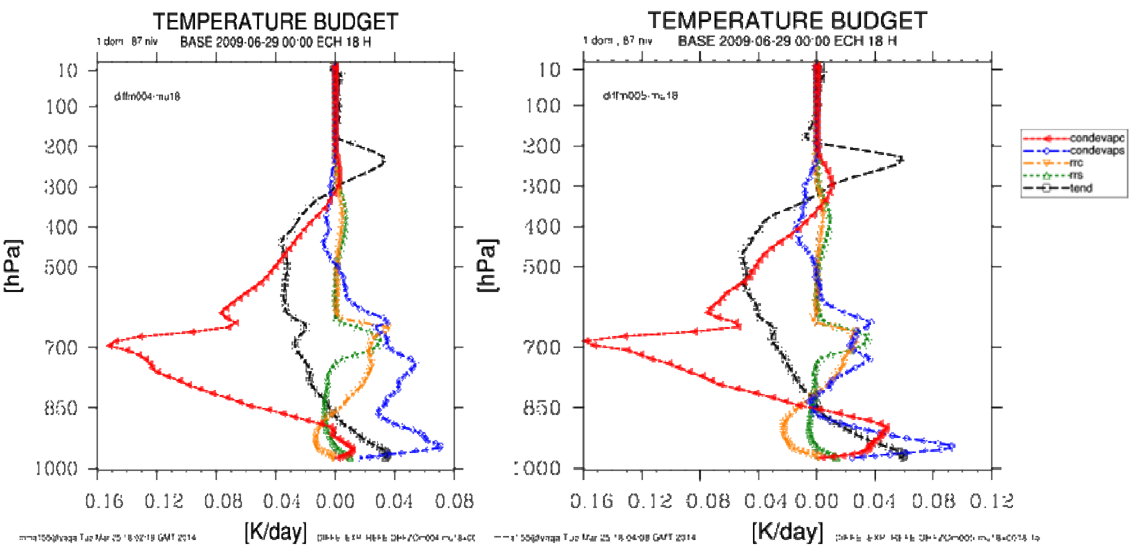


Fig. 11 Impact of the downdraught entrainment rate: temperature budget difference between the experiment with TENTRD=1.E-04 (m004 experiment) , respectively TENTRD=2.E-04 and the reference experiment (mu18, TENTRD=0.5E=-4) for 29th of June 2008 18UTC

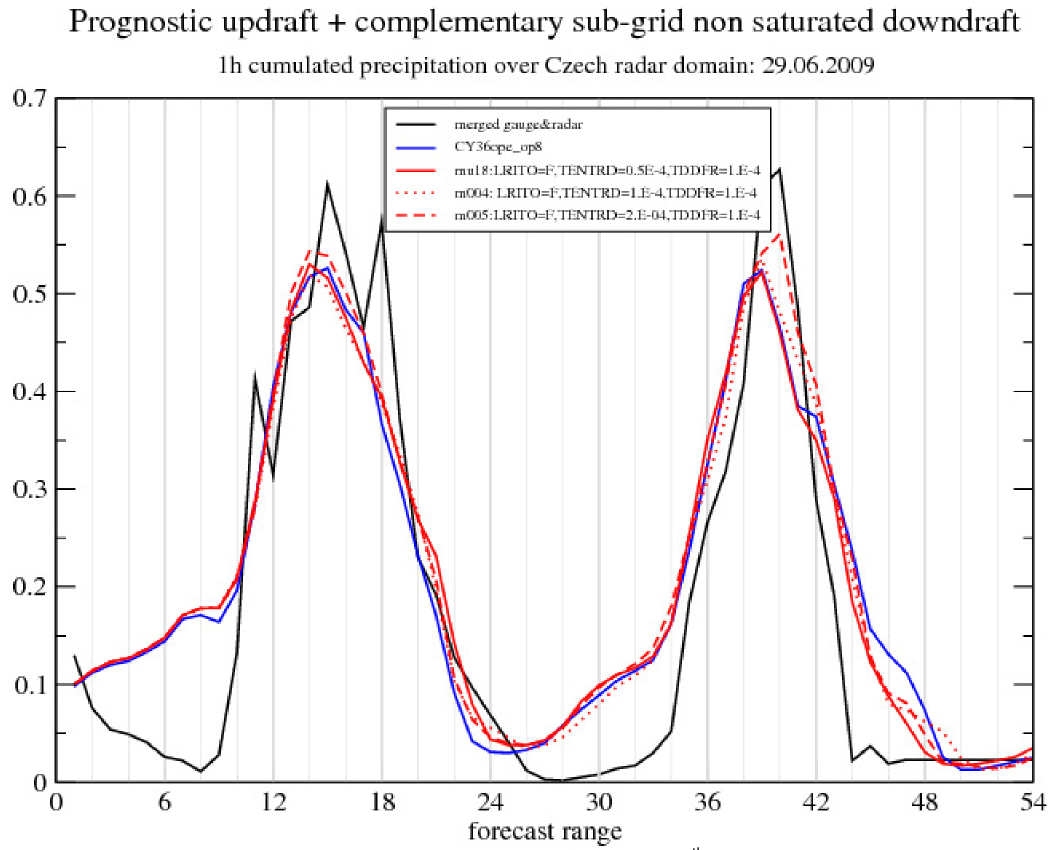


Fig. 12 Precipitation diurnal cycle over the Czech "radar domain" for 29th of June 2009: merged radar & gauges – black line, reference (oop8) – blue line, mu18 (TENTRD=0.5E-04) – red line, m003 (TENTRD=1.E-04) – dot red line and m003 (TENTRD=2.E-04) – dashed red line

As well the diurnal cycle of precipitation is slightly improved by increasing the downdraught entrainment rate for TENTRD=2.E-04 as one can notice on figure 12.

6.2 Variation of the downdraught braking factor

Several experiments were carried out for the tuning of the braking factor to compensate the warming near surface. The best combination of the GDDDP and GDDBETA parameters was found to be (exp. m011):

GDDDP=8.E7 and **GDDBETA=3** in top of **TENTRD=2.E-04**

which gives a little bit better profile of cooling/warming than using the same values as the saturated downdraught:

TENTRD=1.E4 and GDDBETA=2

It seems that a further tuning of the microphysics and/or the updraught is necessary to a obtain a better results.

Finally the temperature budget differences with respect of the reference (d818 - December 2013, for what the verification scores are available) are shown in figure 13, for the same tuning as in December 2013 and for the actual provisional tuning.

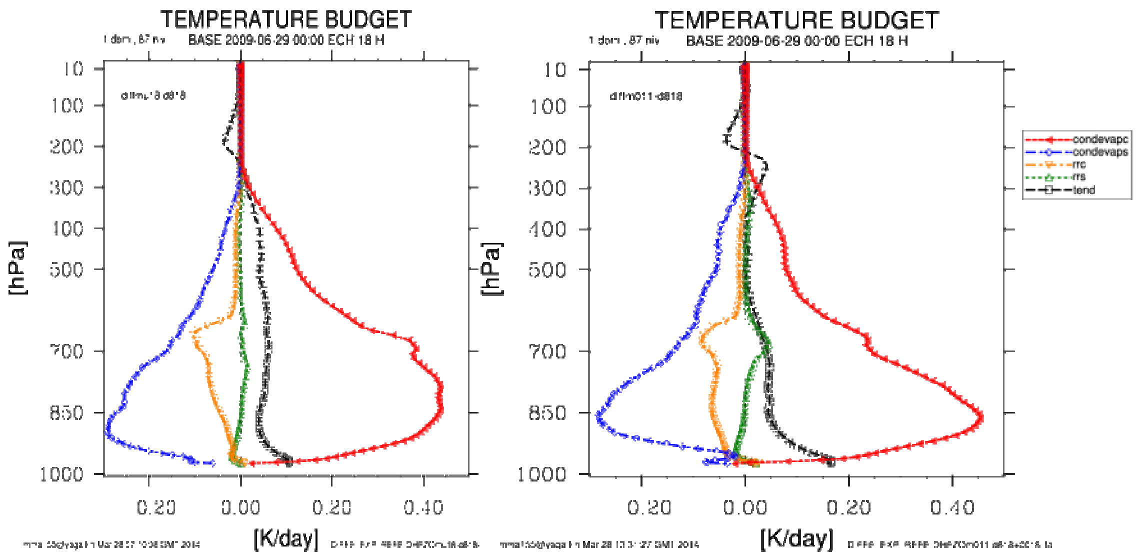


Fig. 13 Temperature budget difference of the experiments with the same tuning as in December (mu18) and to the provisional setup (m011 and the reference (d818) for 29th of June 2008 18UTC

6.3 Objective verification

The 10 days objective verification for actual tuning (m011 experiment set up) confirmed the signalled problems for the 29th of June 2009 simulation, especially for lower troposphere.

The warm temperature bias (fig. 14) is maintained for the upper air levels. With respect to the Alaro operational CHMI version (cy36t1_op8) the m011 simulation shows better scores at 500 hPa between 12 and 54 forecast ranges and a score degradation around 200 hPa level and below 850 hPa.

Objective verification: 21st June – 30th July2009 : temperature bias

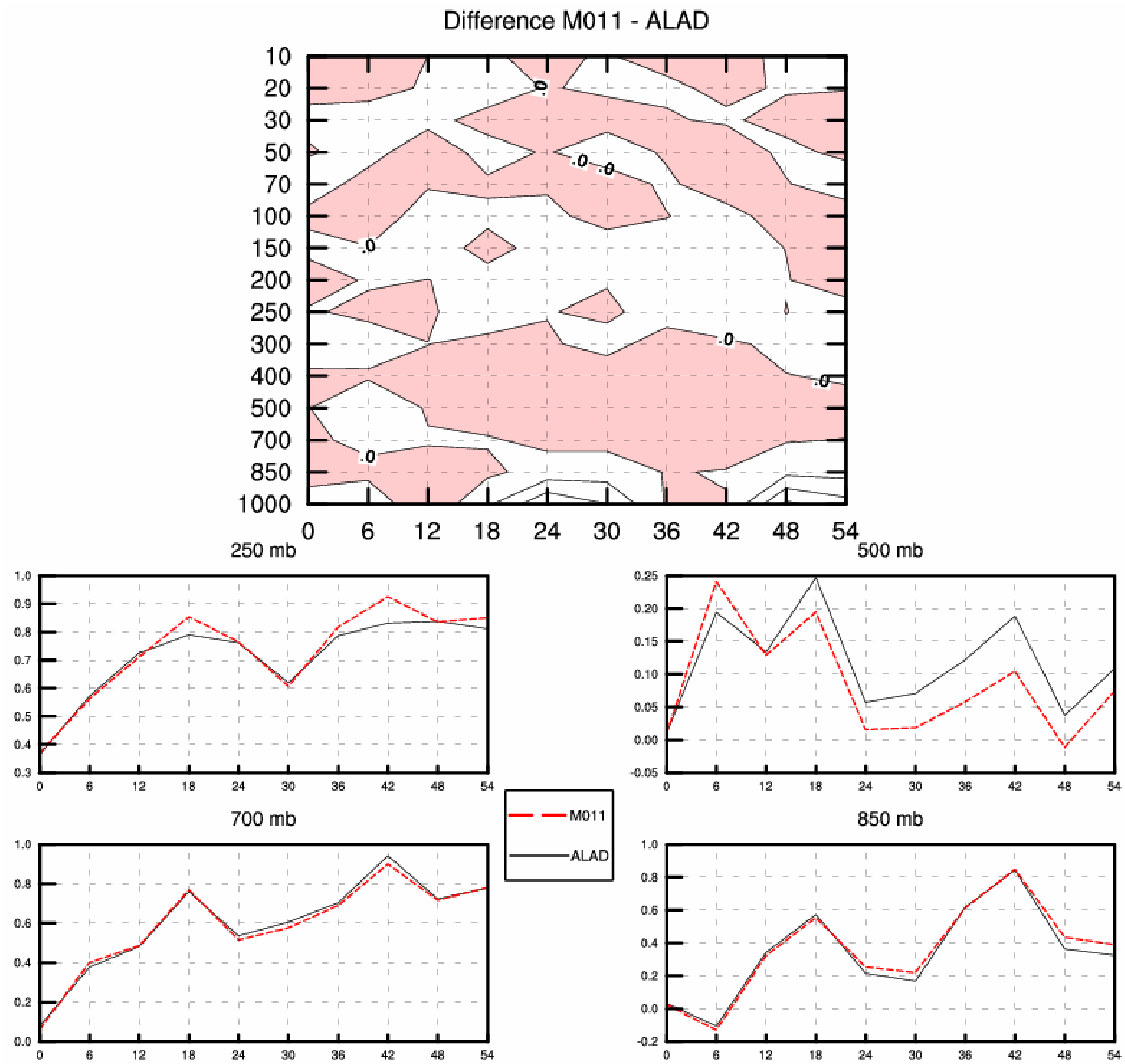


Fig. 14 Temperature bias computed for 21st - 30th of June 2009 period

Near the surface the scores for relative humidity and geopotential are almost neutral. The systematic temperature warm bias is more emphasised for minimum temperature (fig.15). Contrary to the operational reference the m011 simulation bias evolution is smoother, having no diurnal cycle variation.

Objective verification: 21st June – 30th July2009 : surface bias

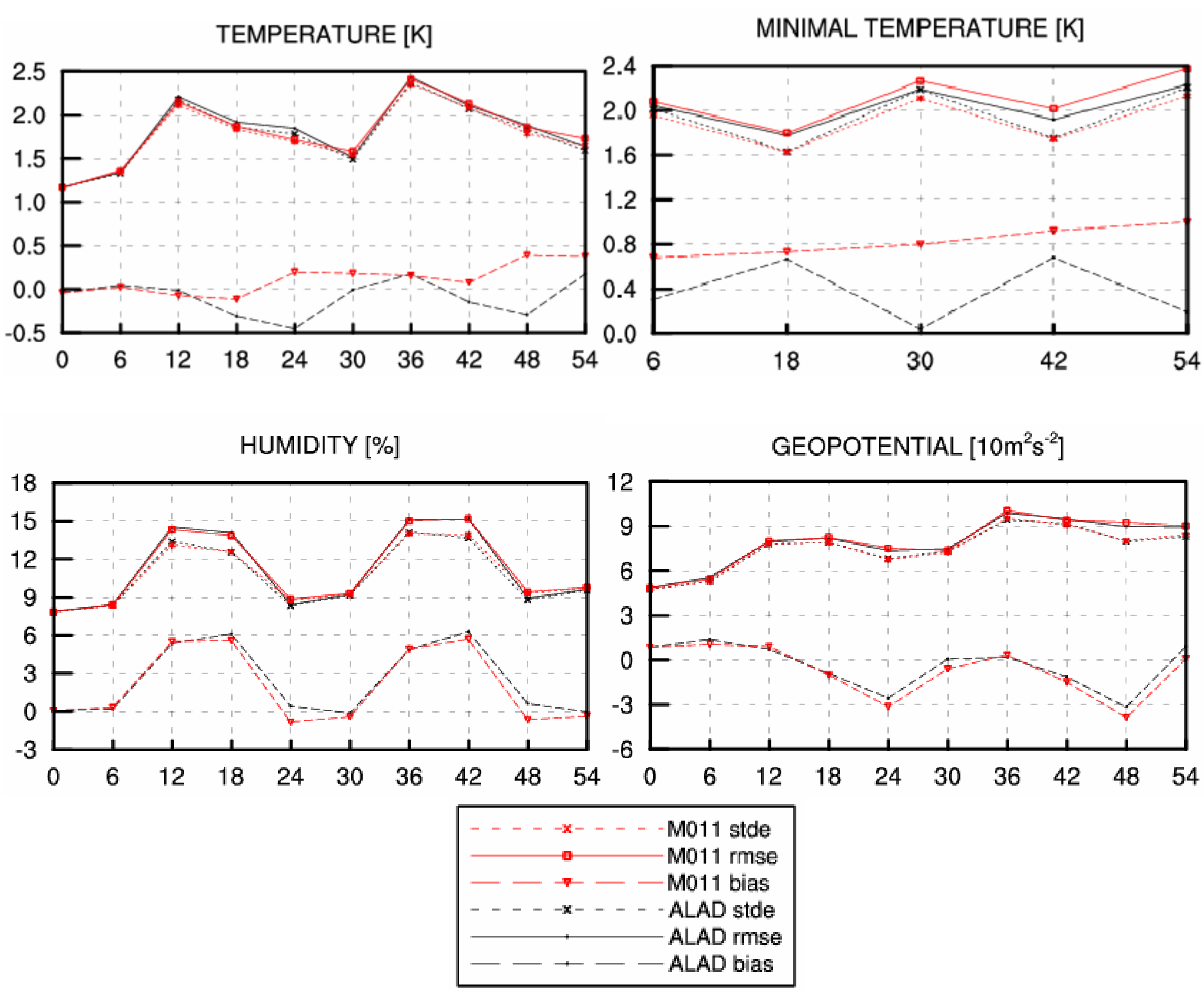


Fig. 15 Temperature. relative humidity and geopotential bias computed for 21st - 30th of June 2009 period