# THE NON-SATURATED DOWNDRAFT IN ALARO-1

**RC-LACE stay report**
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The proposed work of this stay was to get familiar with the source code for non-saturated downdraft, check the code implementation against the documentation provided by Luc Gerard (RMI, Belgium), make some tests with the initial tuning settings and look at specific convection diagnostics (rather than general scores) and some wind gust cases linked to the non-saturated downdraft.

## 1. Source code validation against documentation

The source code for non-saturated downdraft, respectively the subroutine acnsdo.F90 implemented by Luc in ALARO-1vA cy38t1tr_op5 at CHMI, was validated against the documentation (Gerard 2015a, Gerard 2015b and De Meutter et al. 2015).

I started by getting familiar with the code and trying to understand how the scientific developments were implemented in the subroutine and, at the same time, checking it against the documentation. I've had some questions about parts of the code and Radmila and Luc helped with explanations. I also proposed some changes to the code or comments, which Luc has reviewed and decided to implement. There were also few corrections to the documentation (some sign changes and different values of constant coeffiecients). The changes are described below, lines starting with “<” indicating the old code and lines starting with “>” indicating the new code.

**(1) line 84**

```
< ! - 2D (0:KLEV) .
---
> ! - 2D (1:KLEV) .
```

Change of comments because in the next lines PDDOM and PDDAL are defined on full levels (KLON,KLEV)

**(2) line 360**

```
< ! - TEMPORAIRE(S) 2D (1:KLEV) .
---
> ! - OUTPUT 2D (0:KLEV) .
```

Change of comments because next lines describe the output fluxes PDIFCQD, PDIFCQLD, PDIFCQID, PDIFCSD, PSTRCUD and PSTRCVD defined on half levels (KLON,0:KLEV)

**(3) line 436**

```
< INACT(:,:)=0
---
> INACT(:,:)=0_JPIM
```

**(4) line 437**

```
> ZDDOM(:,KTDIA)=0._JPRB
```

The ZDDOM value at KTDIA is needed at lines 478-484 and 1300-1305. But ZDDOM is only defined for KTDIA+1:KLEV at lines 438-447.
The solution is to initialize the value of ZDDOM for KTDIA at line 437.

**(5) line 467**

```
< ! ** MUST ENSURE ZPSIG<1 FOR ZUSIGE **
---
> ! ** MUST ENSURE ZSIG<1 FOR ZUSIGE **
```

**(6) line 472**

```
>    ZSIG9(JLON)=ZSIG(JLON)
```

Update of  ZSIG9 so that the code for ZSIGX at lines 921-924 and for ZEXP at line 967 corresponds to documentation (eq. 29 and 30 on page 9).

**(7) line 656**

```
< ! ZCP       : AS PZLH BUT FOR THE SPECIFIC HEAT CP.
---
> ! ZCP       : AS ZLH BUT FOR THE SPECIFIC HEAT CP.
```

**(8) line 779**

```
<     ZOC=ZSA(JLON)*ZZ2+ZSB(JLON)*ZZ-ZSC(JLON)*ZB0
---
>     ZOC=ZSA(JLON)*ZZ2+ZSB(JLON)*ZZ-ZSC(JLON)*ZB0*ZK1
```

Here ZOC corresponds to zoc≡γ in eq. (54) on page 17 in documentation:

$$\underbrace{\left[a\left(B_1 - \frac{f_n^{\overline{l-1}}}{\Delta t} + E\right) + b\left(\frac{1}{\Delta t} + \frac{o^{l-1}}{\Delta p^{\overline{\overline{l-1}}}}\right) - cB_0\right]}_{zoc\equiv\gamma}$$

Last term in the code is ZSC(JLON)*ZB0 = $c'B_0$ , but instead it should be equal to $cB_0$ . According to eq. (52) on page 16 in documentation we have $c=Kc'$ , therefore the last term should be multiplied by $K$ (ZK1 in the code).

**(9) lines 842-843 and 845:**

```
< ! IF ZZA=1: ZA, ELSE: ZB
<     ZZA=MAX(0._JPRB, SIGN(1._JPRB, ZDELTA))
---
> ! IF ZZB=1: ZB (zdelta<=0), ELSE: ZA (zdelta>0)
>     ZZB=MAX(0._JPRB, SIGN(1._JPRB, -ZDELTA))

<     ZOMD=MAX(0._JPRB, ZOMR(JLON,JLEV-1), ZZZ*(ZZA*ZA + (1._JPRB-ZZA)*ZB))
---
>     ZOMD=MAX(0._JPRB, ZOMR(JLON,JLEV-1), ZZZ*(ZZB*ZB + (1._JPRB-ZZB)*ZA))
```

In the old code, the solution will correspond to ZA for ZDELTA≥0 (i.e. $z_0$ for $\Delta\geq 0$) and to ZB for ZDELTA<0 (i.e. $z_k$ for $\Delta<0$). But the documentation indicates that the formula for $\Delta=0$ is a simplification for the case $\Delta\leq 0$. The code was changed in order to have ZA for ZDELTA>0 (i.e. $z_0$ for $\Delta>0$) and ZB for ZDELTA≤0 (i.e. $z_k$ for $\Delta\leq 0$).

**(10) lines 917-918**

```
<     ZZ2=MAX(0._JPRB,SIGN(1._JPRB,ZFORM(JLON,JLEV-2)*ZFEVP(JLON,JLEV-2)&
<                &    -ZFORM(JLON,JLEV-1))*ZFEVP(JLON,JLEV-1))
---
>     ZZ2=MAX(0._JPRB,SIGN(1._JPRB,ZFORM(JLON,JLEV-1)*ZFEVP(JLON,JLEV-1)&
>                &    -ZFORM(JLON,JLEV-2)*ZFEVP(JLON,JLEV-2)))
```

Misplaced paranthesis at line 918.
Also, the 1/3 and 99% evaporation fractions were inverted. To correct this, the vertical indexes of ZFORM and ZFEVP were changed.

## 2. Testing the non-saturated downdraft with initial tuning settings provided by Luc

The non-saturated downdraft subroutine is activated by LNSDO=.T. key in the namelist. The namelist settings with initial tuning for runing with non-saturated downdraft were provided by Luc:

```
GDDALBU=0.9,     ! COEFF OF BUOYANCY ACCOUNTING FOR VARIOUS EFFECTS
GDDBETA=2.,     ! DOWNDRAUGHT EXPLICIT DETRAINMENT COEFFICIENT
GDDDP=1.E4,     ! DELTAp FROM SURFACE BRAKING LAYER
GDDENDYMX=1.E-4,     ! LIMITATION OF DYNAMICAL ENTRAIMENT IN DD
GDDFP(3)=5.2,     ! INTENSIFICATION OF F(PRECIP) IN ACNSDO
GDDFRAC=0.01,     ! FRACTION OF PRECIPITATION AREA OCCUPIED BY DD
GDDFREVS=0.5,     ! FRACTION OF STRATIFORM EVAPORATION TO SCALE DD EVAPORATION
GDDINHOM=2.,     ! GAIN FOR PRECIP INHOMOGENEITY IN DOWNDRAFT
GDDTAUSIG=-1800.,     ! RELAXATION TIME FOR DOWNDRAFT MESH FRACTION
TDDFR=16.E-4,     ! DOWNDRAUGHT DISSIPATION COEFFICIENT
TENTRD=12.E-5,     ! DOWNDRAUGHT ENTRAINMENT RATE (s2/m2)
```

For future tuning, TDDFR, TENTRD and GDDTAUSIG are the main parameters to consider.
The non-saturated downdraft configuration (with the above initial namelist settings) was tested against the referrence operational configuration for two convective cases for Czech Republic domain.

### 2.1 Case of 29$^{th}$ of June 2009

This case was also investigated by Doina Banciu in a previous stay. Intense convective precipitation (up to 73 mm in 6 hours) were registered between 12 and 18 UTC in the Czech Republic. Compared to the reference, no significant differences were found for the precipitation (figure 1) and wind gust fields. A diagnose of the downdraft evaporation flux (figure 2) shows that it is too weak in the non-saturated downdraft experiment compared to the reference case.

Some futher tuning may be needed and Luc suggested to assess the impact of modifying parameters TENTRD and TDDFR.

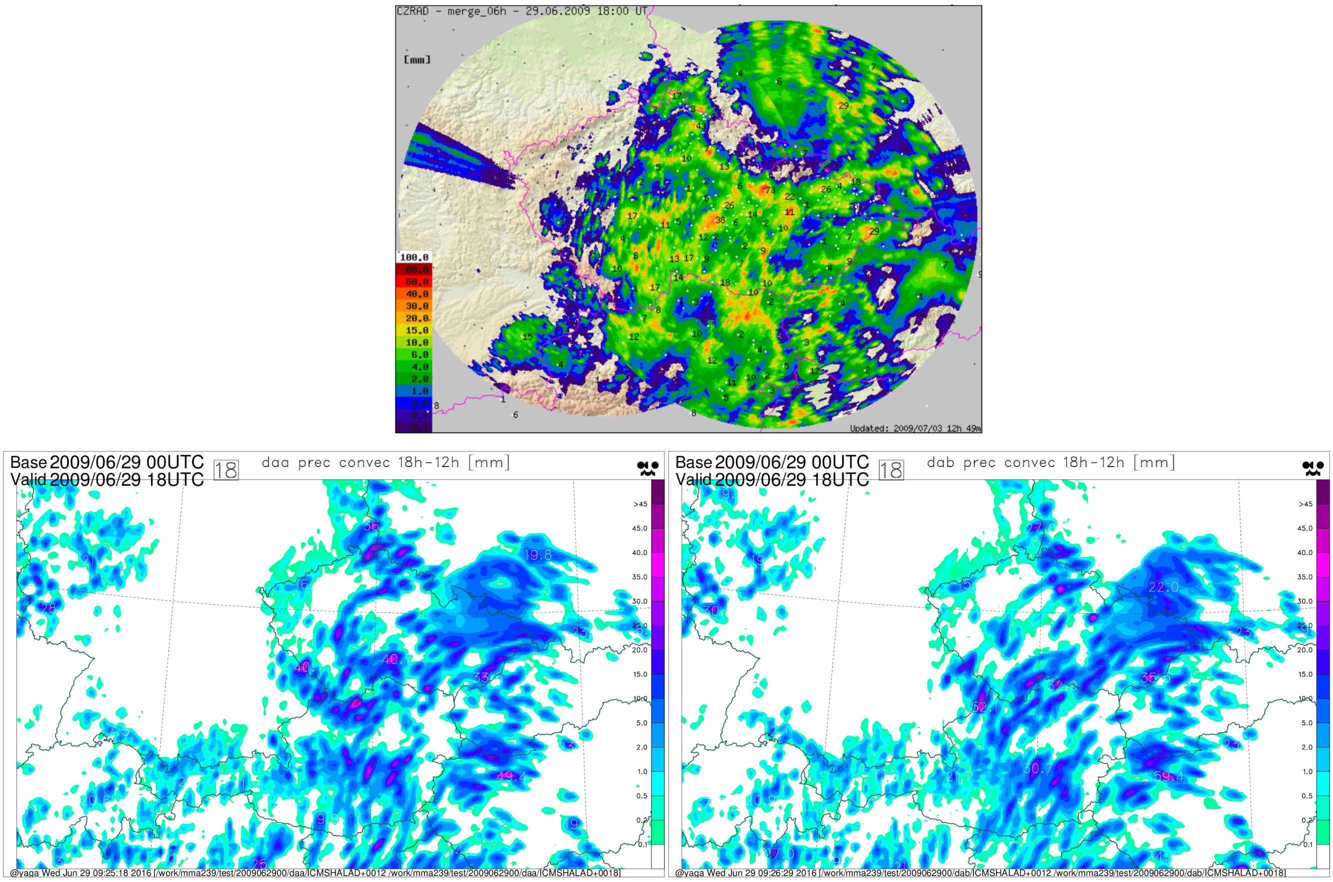


Figure 1: 6h accumulated precipitation (12-18 UTC) for 29th of June 2009: radar measurements (top) and ALARO-1 forecast for the reference (bottom-left) and non-saturated downdraft (bottom-right) experiments

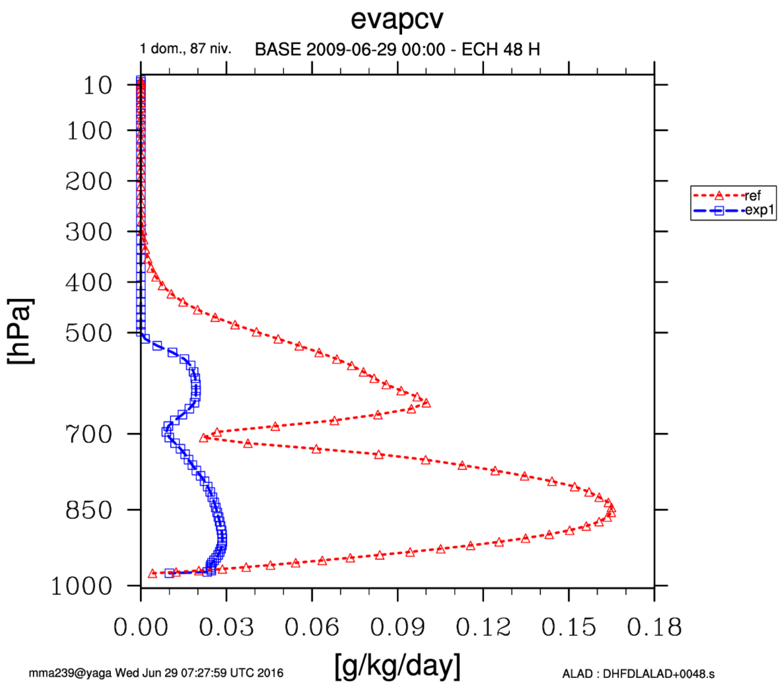


Figure 2: The vertical profile of the convective evaporation flux for 29th of June 2009: the reference experiment (red) and the non-saturated downdraft experiment (blue)

## 2.2 Case of 25th of June 2016

The operational forecast for 25th of June 2016 showed intense convective activity over Czech Republic starting with 12 UTC and continuing until the end of the day. As it can be seen in figure 3, high values for CAPE and moisture convergence were forecasted for 18-21 UTC, together with intense precipitations and wind gusts associated with the convective downdrafts.

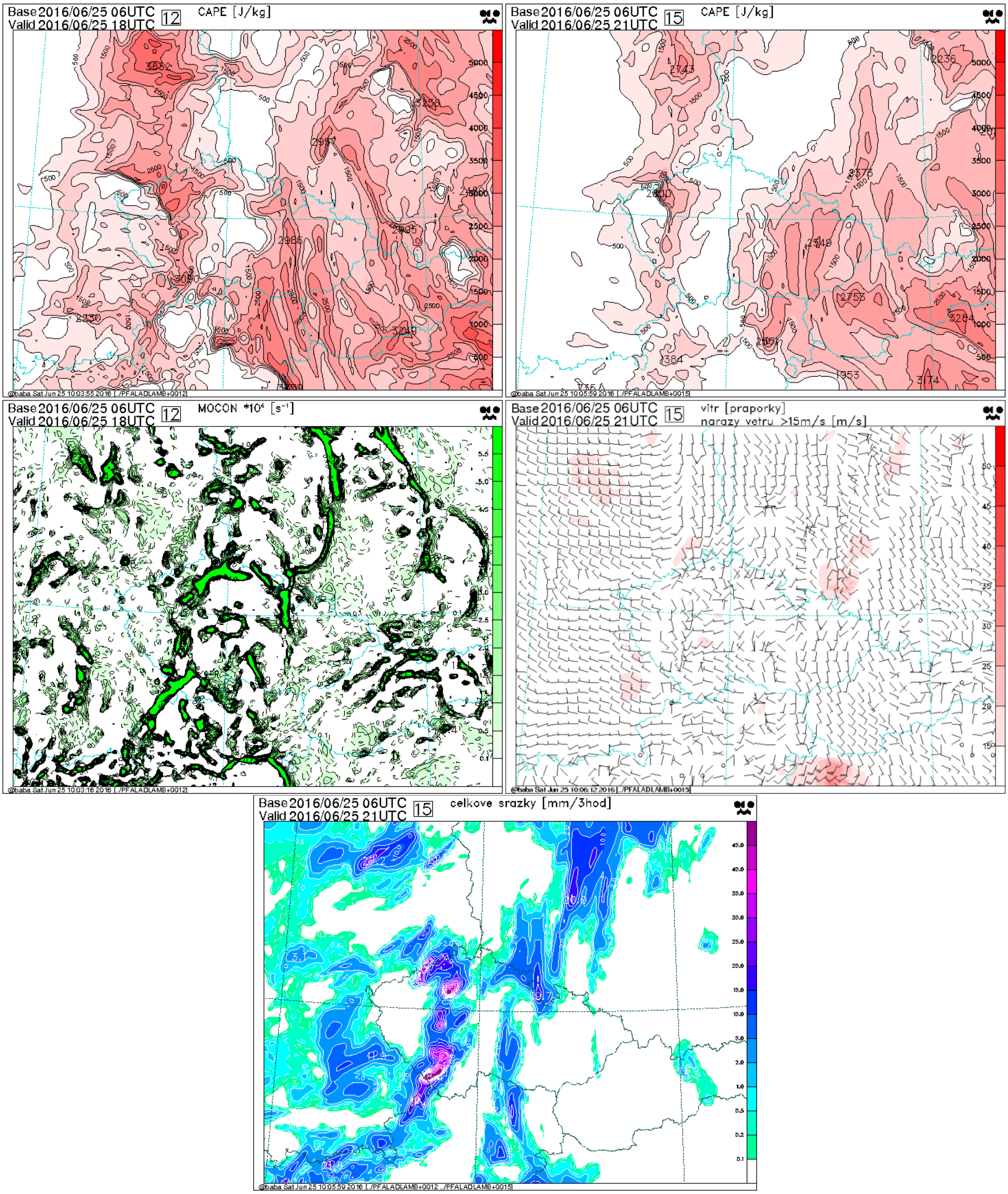


Figure 3: CAPE for 25th of June 2016 at 18 and 21 UTC (top), moisture convergence at 18 UTC (middle left), 10m wind gust at 21 UTC (middle right) and 3h accumulated precipitation during 18-21 UTC (bottom)

Also for this case, the downdraft evaporation flux in the non-saturated downdraft experiment is too weak compared to the reference case (figure 4).

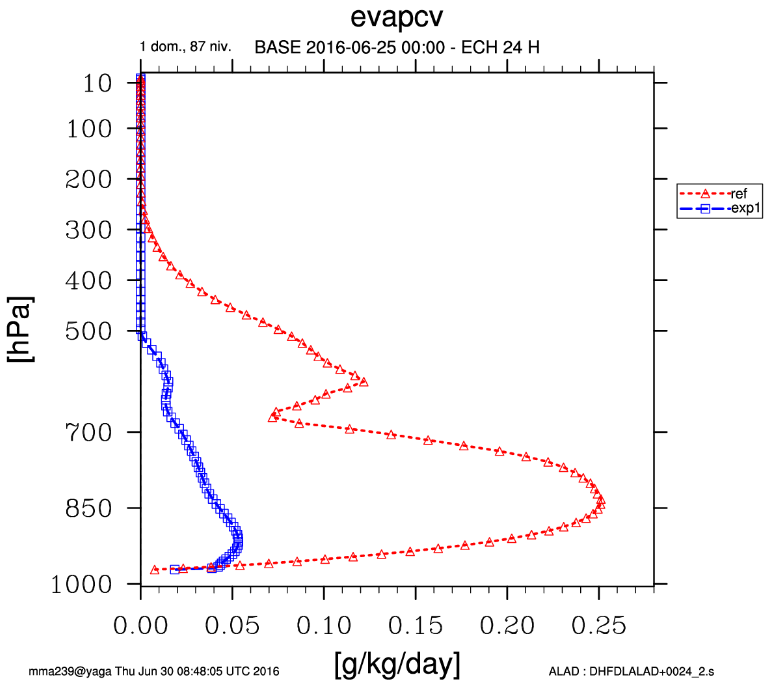


Figure 4: The vertical profile for the convective evaporation flux for 25th of June 2016: the reference experiment (red) and the non-saturated downdraft experiment (blue)

The reference and the non-saturated downdraft experiments show similar precipitation fields in terms of both location and intensity (figure 5, top) and there were no significant differences in the 10 m wind gust.

For additional diagnosis, we have looked at the vertical velocity and dowdraft mesh fraction in the two experiments. The downdraft mesh fraction is well represented in the non-saturated downdraft experiment, with values of 0.3 – 0.5 at many levels and up to 1 (figure 5 middle). For the vertical velocity (figure 5 bottom), the reference experiment shows higher values and a larger scale field, while the non-saturated downdraft experiment shows a more realistic pattern and smaller values. The saturated downdraft appears to be active at many unlikely places, while the non-saturated downdraft is more focused on the actual precipitation areas.

The difference in coverage of the downdraft could explain the difference in domain-averaged evaporation. For future work Luc suggested to also look at the final total water vapour tendency (downdraft + microphysical evaporation), which is what matters for the model state and evolution.

The work should continue with tuning of some parameters (for example TENTRD, TDDFR) and more diagnostics and evaluation of the non-saturated downdraft scheme.

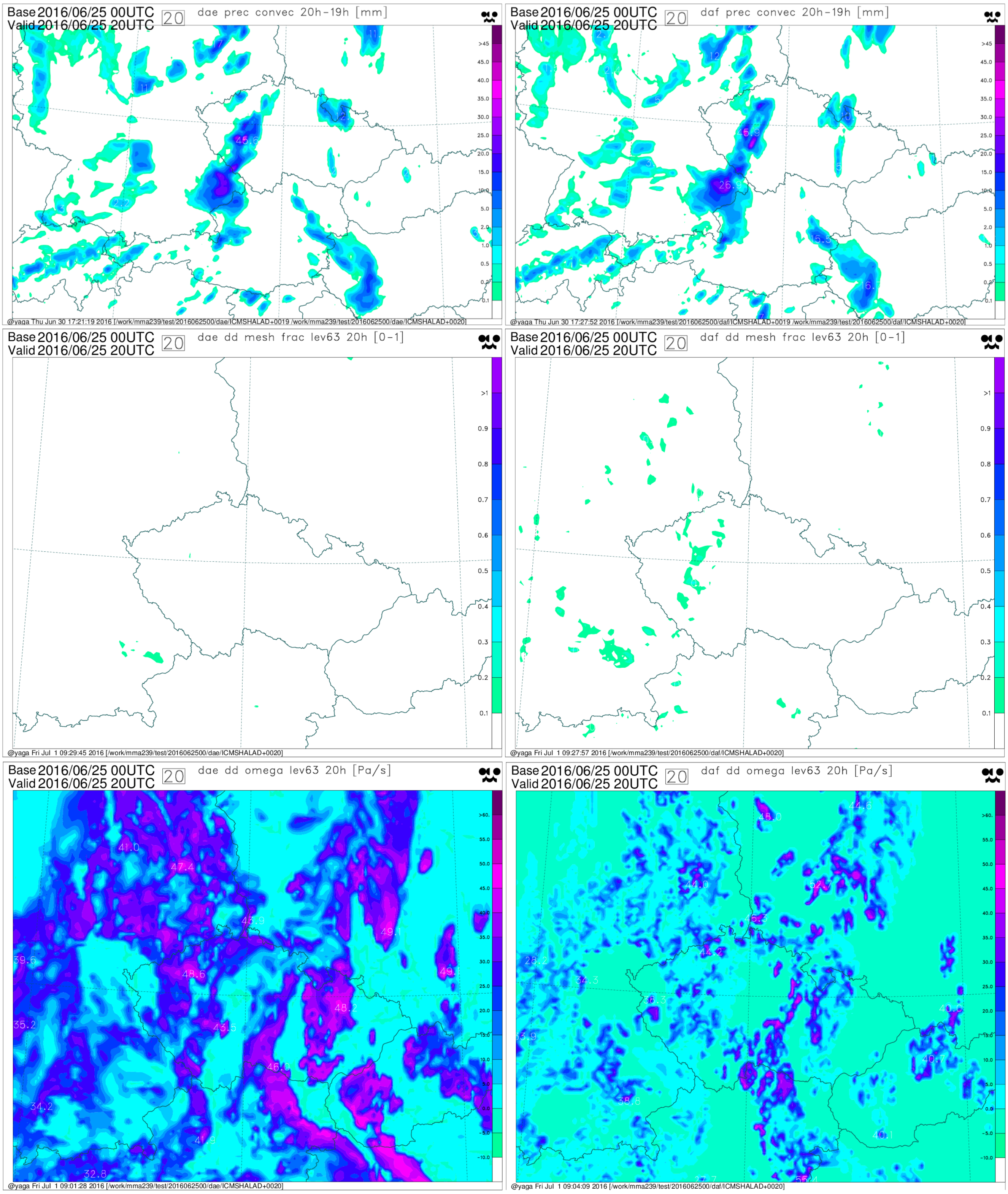


Figure 5: 1h accumulated precipitation (19-20 UTC) for 25th of June 2016 (top), downdraft mesh fraction (middle) and vertical velocity (bottom) at 20 UTC for model level 63 (approx. 1500 m), in the reference experiment (left) and the non-saturated downdraft experiment (right)

## References


L. Gerard, 2015a: Unsaturated downdraft documentation.

L. Gerard, 2015b: Bulk mass-flux perturbation formulation for a unified approach of deep convection at high resolution. *Monthly Weather Review*, **143**, 4038-4063.

P. De Meutter et al., 2015: Predicting small-scale, short-lived downbursts: case study with the NWP limited-area ALARO model for the Pukkelpop thunderstorm. *Monthly Weather Review*, **143**, 742-756.