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***L**imited **A**rea Modeling in **C**entral **E**urope*

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Modification of EDKF parametrization in the grey zone

Joint 25th ALADIN Workshop & HIRLAM All Staff Meeting 2015,
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DHMZ OMSZ ZAMG ROMANIA ANM

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- Shallow convection parametrization in AROME and grey zone problem
- Modifications:
  - 1) New initialization of Mass-Flux
  - 1bis) Randomization of the initialization by Honnert
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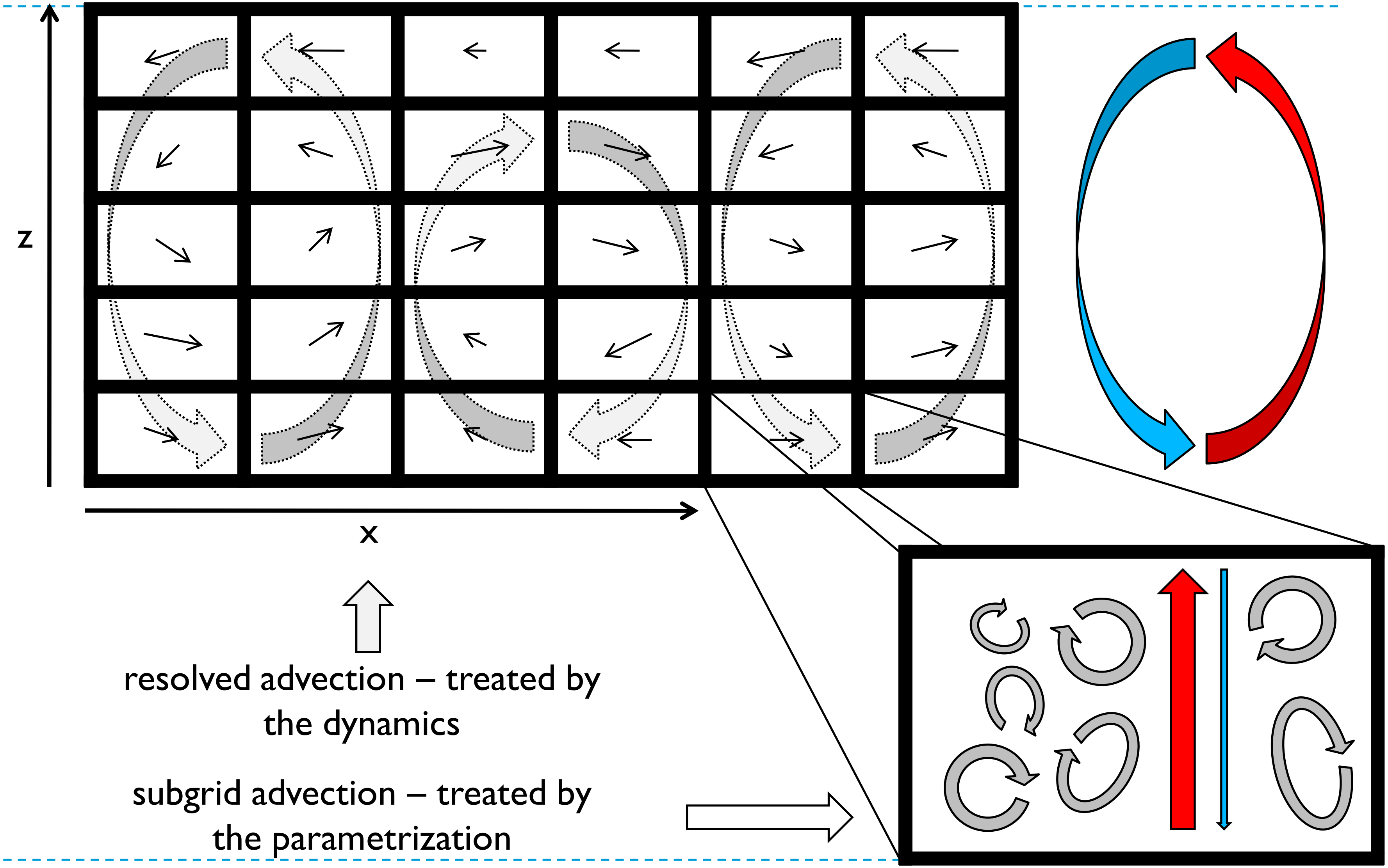
  - 3) New set of Mass-Flux equations by Honnert
- Future plans

Shallow convection



resolved advection – treated by the dynamics

subgrid advection – treated by the parametrization

Grey zone problem

- The shallow convection:
- at low resolution (dx>~2km) is parametrized
- at high resolution (~125m>dx) is not parametrized – it is treated by the dynamics
- What happens between?
- The model's dynamics partly resolves the shallow convection eddies, while the parametrization is still needed → **GREY ZONE**
- Solution: we have to find a parametrization, which is scale-adaptive → depends on the resolution

Parametrization of turbulent flux

In AROME:

- K-theory + Mass-Flux

$$\overline{w'\phi'} = \boxed{-K\frac{\partial\bar{\phi}}{\partial z}} + \boxed{M(\phi_u - \bar{\phi})}$$

$$M = a_u(w_u - \bar{w})$$

Eddy Diffusion Mass-Flux
EDMF → EDKF (Kain - Fritsch parametrization)

w - vertical velocity
ϕ - arbitrary variable
$\overline{w'\phi'}$ - vertical turbulent flux
$\partial\bar{\phi}/\partial z$ - vertical gradient of Φ
K - turbulent diffusion coefficient
$\bar{w}, \bar{\phi}$ - mean of w and Φ
w_u, ϕ_u - mean of w and Φ in the updraft area
a_u - updraft area
ρ - density

Note: according to an other definition:

$$\overline{w'\phi'} = -K\frac{\partial\bar{\phi}}{\partial z} + \frac{M}{\rho}(\phi_u - \bar{\phi})$$

$$M = a_u\rho(w_u - \bar{w})$$

The Mass-Flux algorithm (just sketch)

g - grav. acceleration

$\overline{\theta_v}$ - virt. pot. temperature

$\overline{w'\theta'_v}_{grd}$ - buoyancy flux at the ground [Km/s]

L_{BL89} - Bougeault-Lacarrère upward mixing length

INITIALIZATION

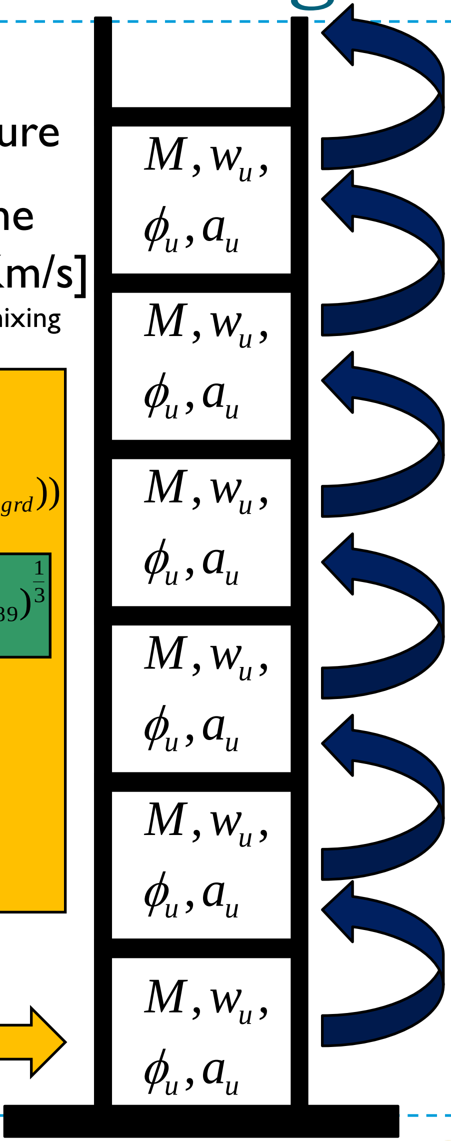
$$w_u^2(z_{grd}) = \max(0.0001\frac{m^2}{s^2};\frac{2}{3}TKE(z_{grd}))$$

$$M(z_{grd}) = XCMF*(\frac{g}{\overline{\theta_v}}\overline{w'\theta'_v}_{grd}L_{BL89})^{\frac{1}{3}}$$

$$a_u(z_{grd}) = \min(\frac{M}{\sqrt{w_u^2}};0,33)$$

$$w_u^2(z_{grd}) = \left(\frac{M}{a_u}\right)^2$$

note: the original equations contain density



$$\frac{1}{M}\frac{\partial M}{\partial z} = (\varepsilon - \delta)$$

$$\frac{\partial \phi_u}{\partial z} = -\varepsilon(\phi_u - \bar{\phi})$$

$$w_u\frac{\partial w_u}{\partial z} = aB - b\varepsilon w_u^2$$

ε - entrainment

δ - detrainment

B - buoyancy

Upward integration:

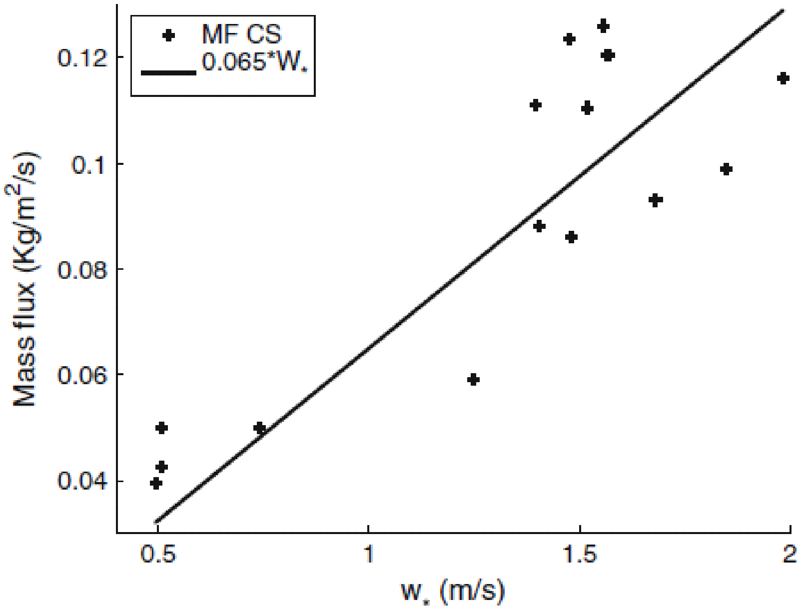
1. Checks if we reached the LCL (lifting condensation level)
    - a) No - ε,δ are computed by Pergaud
    - b) Yes - ε,δ are computed by Kain and Fritsch
2. Computes: M, w_u, Φ_u, a_u

Modification (1)

$$\boxed{M(z_{grd}) = XCMF*\left(\frac{g}{\overline{\theta_v}}\overline{w'\theta'_v}_{grd}L_{BL89}\right)^{\frac{1}{3}}}$$

z_i – height of the mixing layer

vertical velocity scale: $$w_* = \left(\frac{g}{\overline{\theta_v}}\overline{w'\theta'_v}_{grd}z_i\right)^{\frac{1}{3}} \quad \text{,if} \quad \overline{w'\theta'_v}_{grd} \geq 0$$



$$M = XCMF*w_*$$

⬇

$$XCMF = 0.065$$

Current value in AROME

Mass-Flux values in the function of w_* according to LES data

(**PERGAUD at al. 2009**)

PERGAUD, J., V. MASSON, S. MALARDEL and F. COUVREUX, 2009: ***A Parametrization of Dry Thermals and Shallow Cumuli for Mesoscale Weather Prediction. Bound.-Layer Meteor.*****, 132, 83-106**

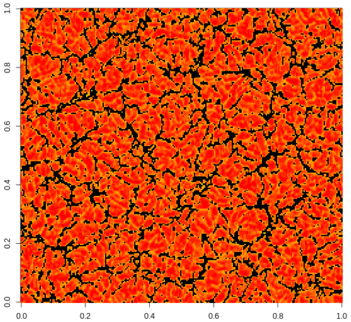
Modification (1)

We used horizontal spatial means of LES (dx = 62.5 m, IHOP, ARM) to get the theoretical values of the tracer concentration and vert. velocity (Honnert at al. 2011)

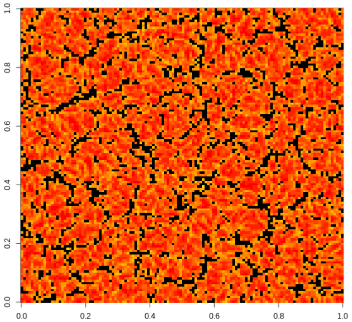
Structure of the surface tracer conc. → estimations of Mass-Flux values (black) by the conditional sampling method:

$P \in CS$ if $w>0$; $w>w_{mean}$; $c-c_{mean}>c_{mean}$,

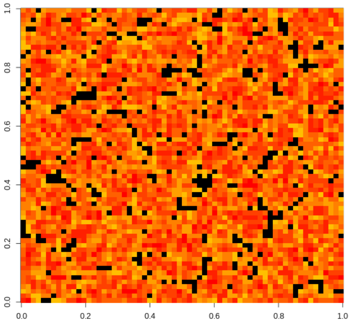
where c – tracer conc., w – vert. velocity



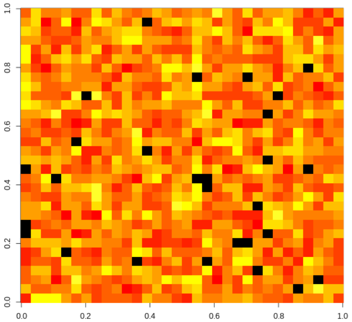
dx = 62.5 m



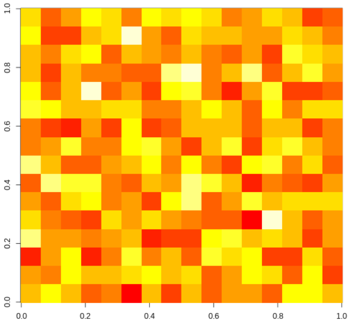
dx = 125 m



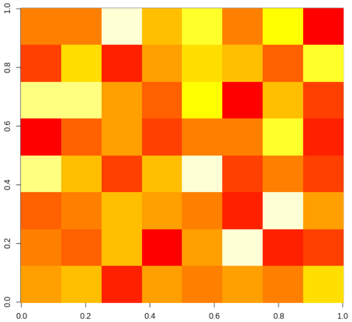
dx = 250 m



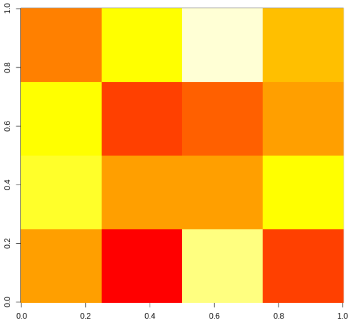
dx = 500 m



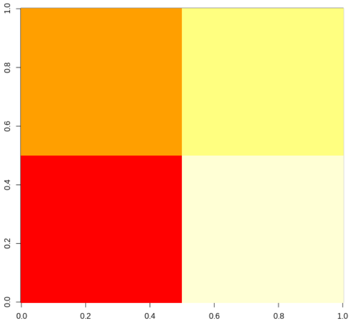
dx = 1000 m



dx = 2000 m



dx = 4000 m



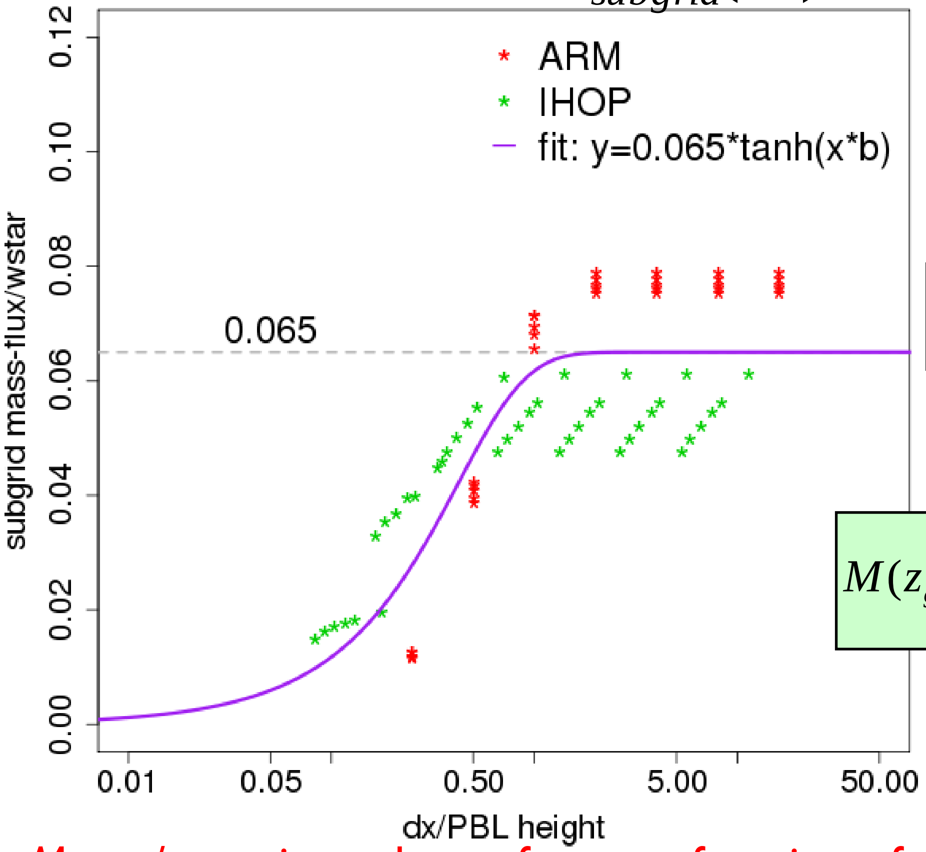
dx = 8000 m

HONNERT, R., V. MASSON and F. COUVREUX, 2011: A Diagnostic for Evaluating the Representation of Turbulence in Atmospheric Models at the Kilometric Scale. J. Atmos. Sci., 68, 3112-3131

Modification (1)

We suppose: $M_{resolved}(62.5m) = M_{total}$

$$M_{subgrid}(dx) = M_{total} - M_{resolved}(dx)$$



$M_{subgrid}/w_*$ ratio at the surface as a function of *dx/PBL height*

Fitted function:

f(x)=0.065*tanh(x*b)

(idea of tanh() → Boutle at al. 2014)

↓

We implemented it into the code:

$$M(z_{grd}) = 0.065 * \tanh\left(\frac{\sqrt{dx * dy}}{h} * 1.86\right) * \left(\frac{g}{\overline{\theta_v}} \overline{w'\theta'_v}_{grd} L_{BL89}\right)^{\frac{1}{3}}$$

In the code:

Possible switch: h = PBL height
h = L_{BL89}

BOUTLE, I. A., J. E. J. EYRE and A. P. LOCK, 2014: Seamless Stratocumulus Simulation across the Turbulent Gray Zone. Mon. Wea. Rev., 142, 1655-1668

Modification (1)

To study the effect of the modification we used idealized AROME simulations - case IHOP

- Examined parameters:

- **TKE** – turbulent kinetic energy [m^2/s^2]
- - subgrid TKE → from the history files

  - resolved TKE → computed with:

$$TKE_{res} = \frac{1}{2}[(u-<u>)^2 + (v-<v>)^2 + (w-<w>)^2]$$

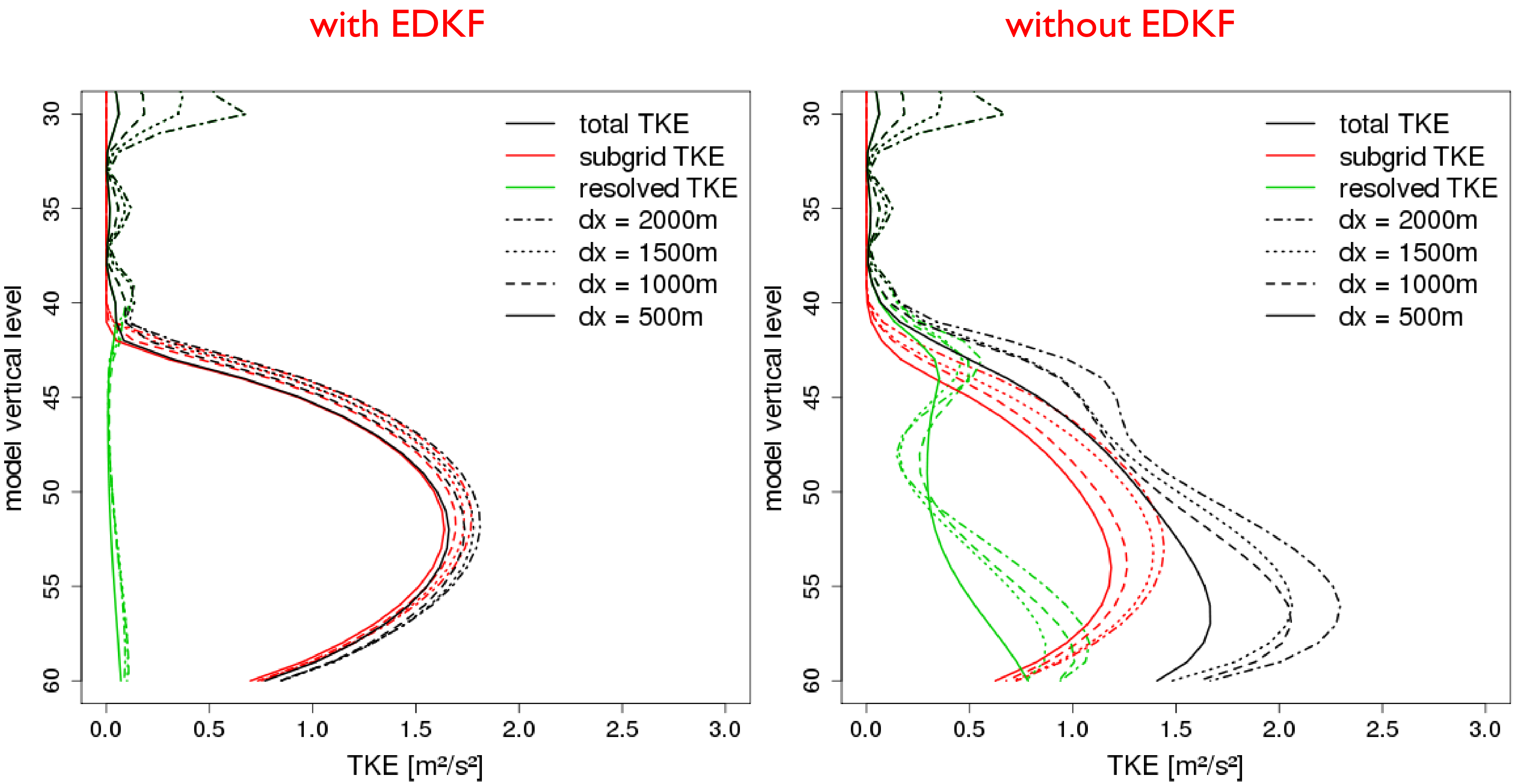
  - total TKE = subgrid TKE + resolved TKE

- **WTHV** – subgrid buoyancy flux [Km/s] (vertical turbulent flux of virtual potential temperature) → from the history files

- (model levels heights: level 60 → ~ 10 m
  level 45 → ~ 1116 m
  level 30 → ~ 4004 m)

Modification (1)

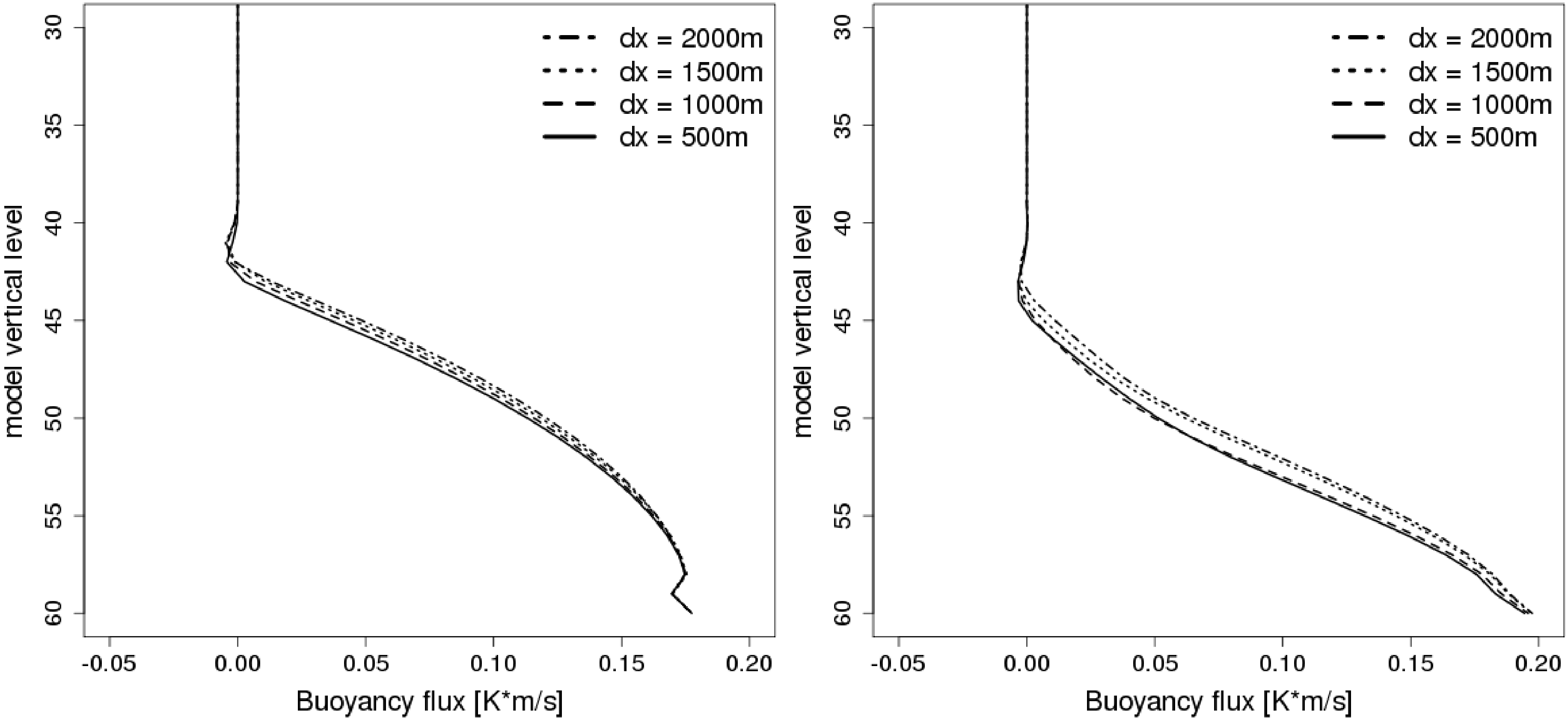
Reference idealized AROME simulations:



The mean total, subgrid and resolved TKE [m^2/s^2]

Modification (1)

Reference idealized AROME simulations:



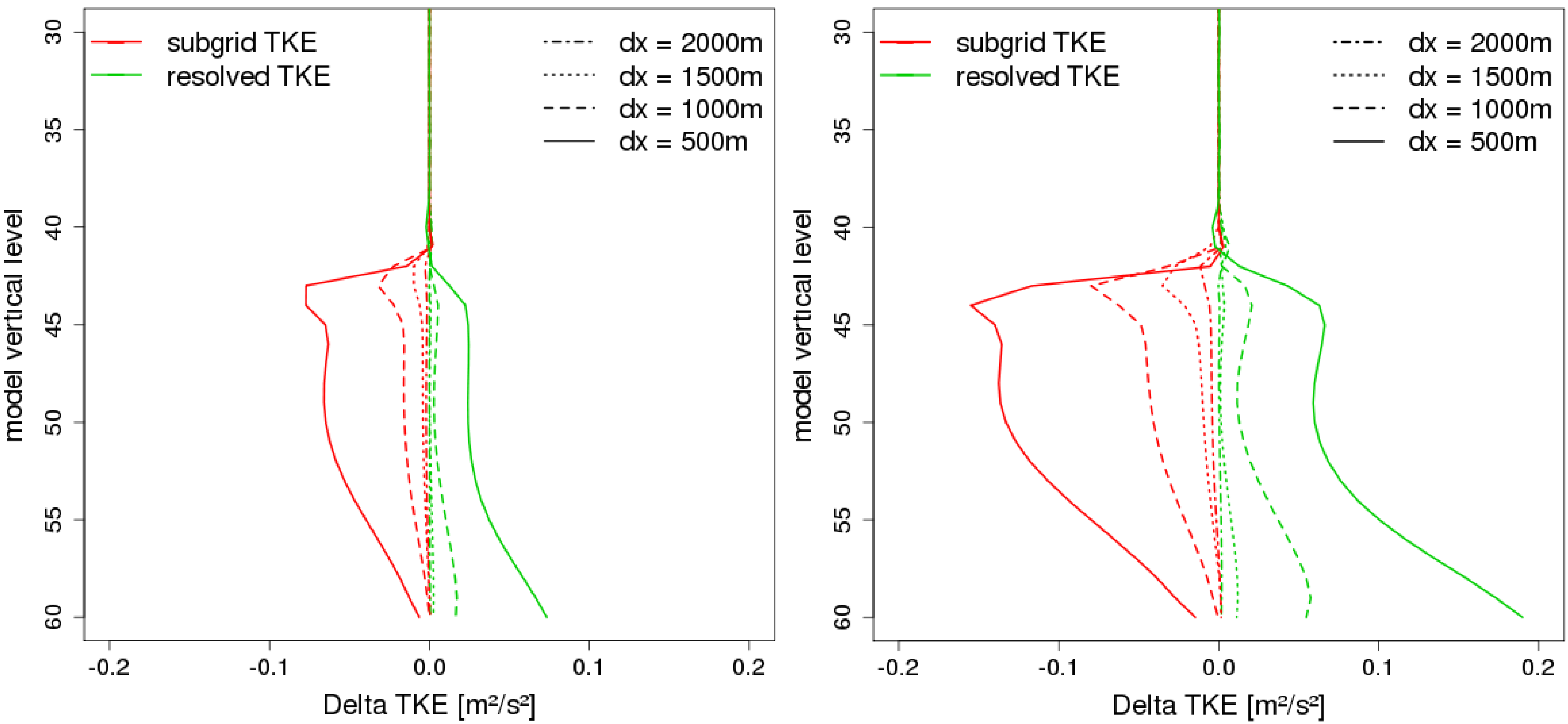
with EDKF

without EDKF

The mean subgrid buoyancy flux [Km/s]

Modification (1)

Differences from the reference:



h = PBL height

h = L_{BL89}

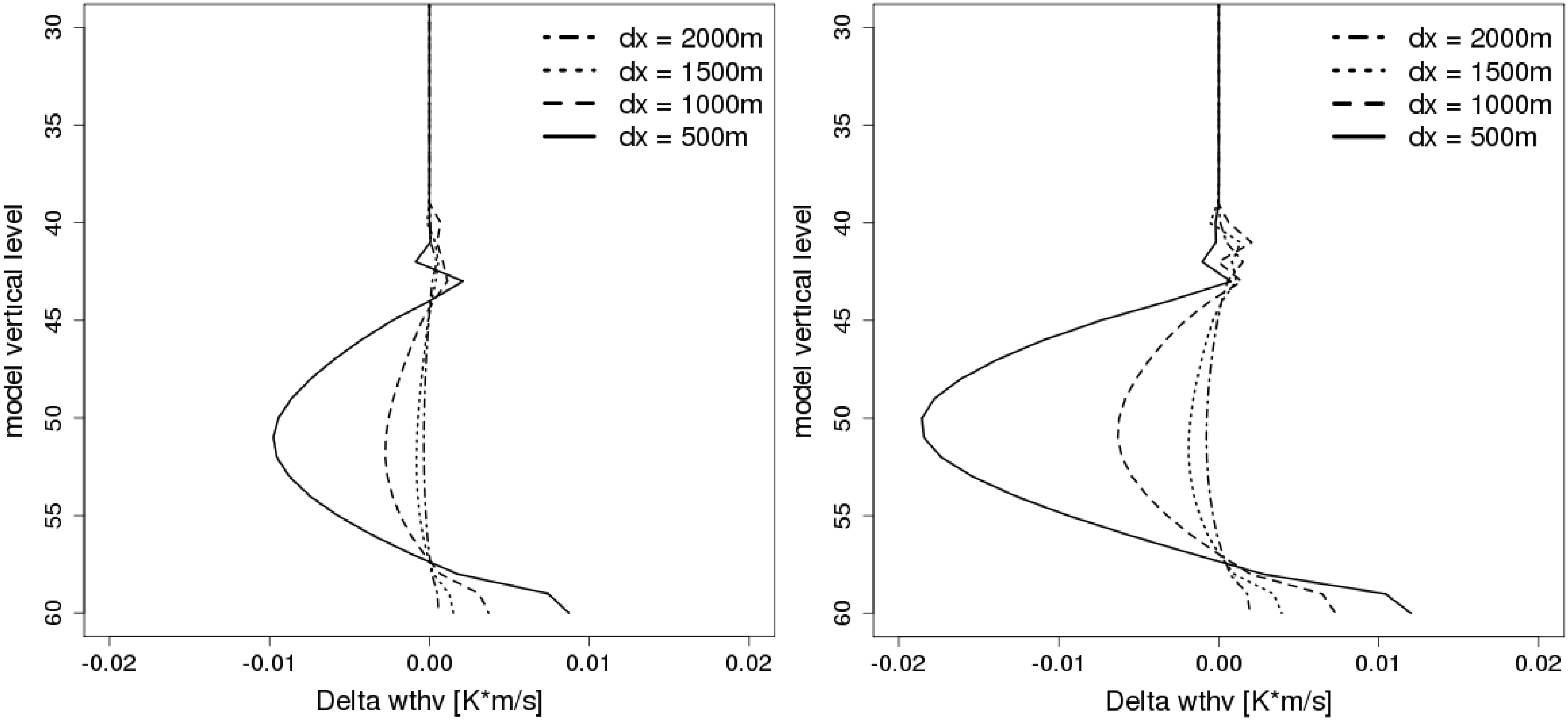
Delta mean subgrid and resolved TKE [m^2/s^2]

Modification (1)

Differences from the reference:

h = PBL height

h = L_{BL89}



Delta mean subgrid buoyancy flux [Km/s]

Modification (1bis)

Randomization of the initialization of Mass-Flux:

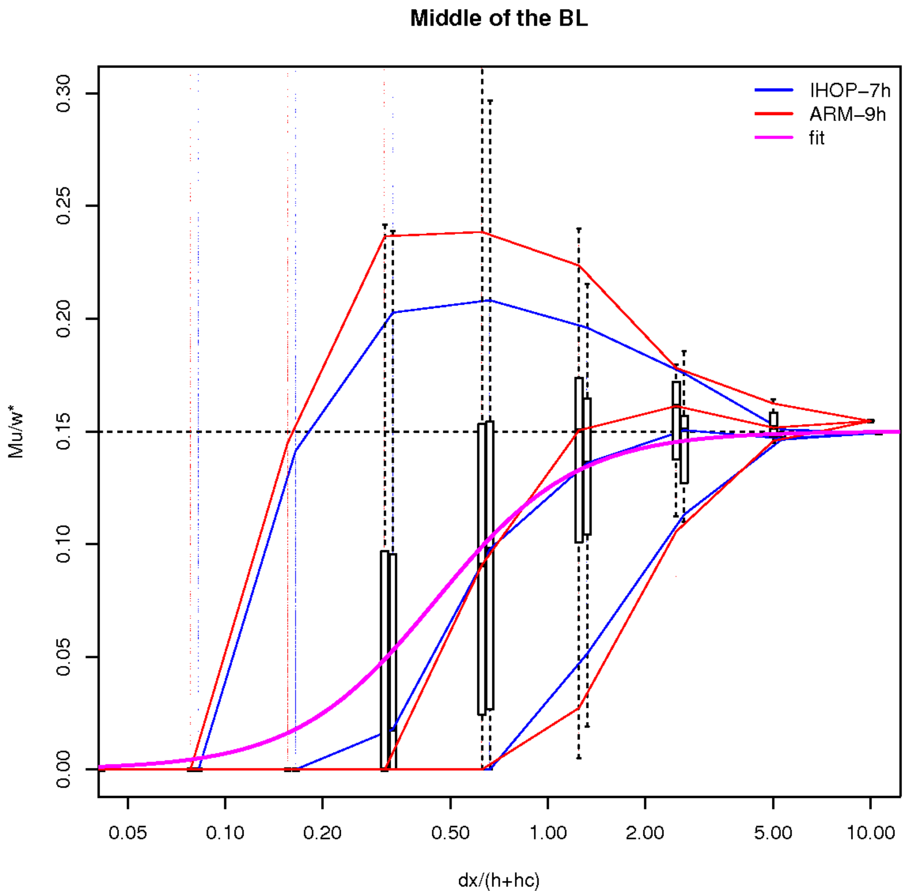
idea by Rachel Honnret

- → The goal is to get more realistic structure of thermal-spacing
- The dispersion of mass-fluxes in the grey zone are not independent on the resolution
- We used Mass-Flux values in the middle of the boundary layer, when they are well developed, to estimate this relationship
- We fitted a log-normal function on these dispersions
- The initialized mass-fluxes are randomly perturbated in the range of this fitted function → factor RAND

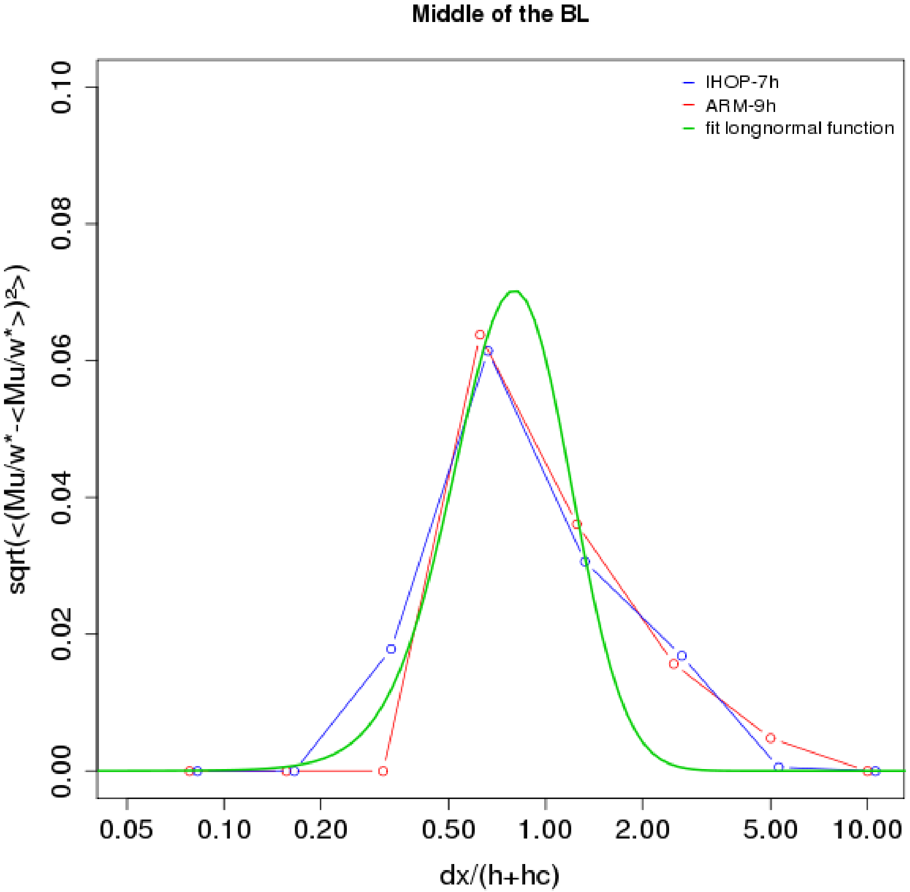
$$\boxed{M(z_{grd}) = 0.065 * \tanh\left(\frac{\sqrt{dx*dy}}{h} * 1.86\right) * \left(\frac{g}{\theta_v}\overline{w'\theta'_v}_{grd} L_{BL89}\right)^{\frac{1}{3}} * RAND\left(\frac{\sqrt{dx*dy}}{h}\right)}$$

Modification (1bis)

Randomization of the initialization of Mass-Flux : Here M_u values were computed for every single point in the averaged LES fields with theoretically ideal values



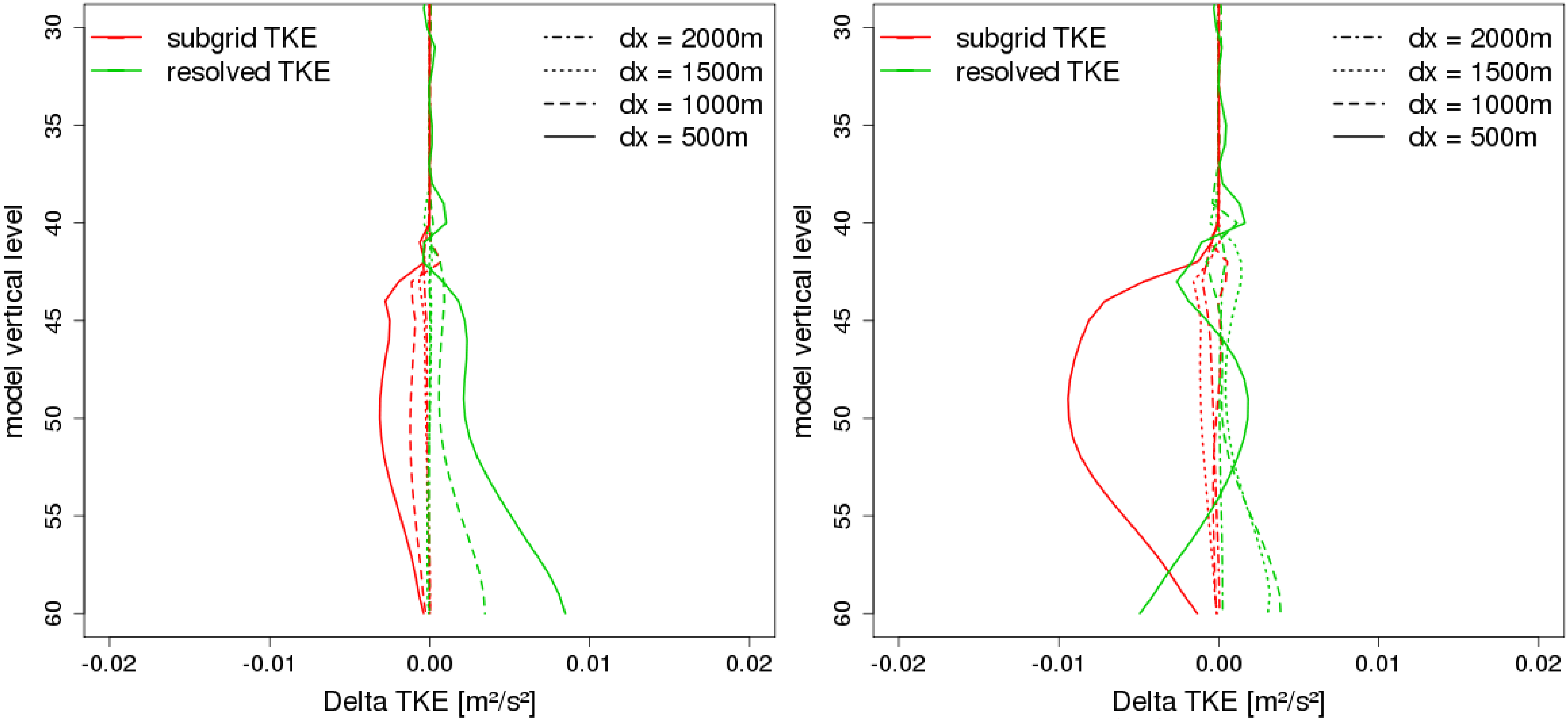
$M_{subgrid}/w_*$ as a function of the *dx/(h+hc) – 5%, 95% quantiles, median, boxplot* – where *h* is the PBL height, *h_c* is the cloud layer height, when the thermals are well developed.



Dispersion of the *$M_{subgrid}/w_*$* as a function of the *dx/(h+hc)*, The green line is the fitted log-normal function.

Modification (1bis)

Differences from the modification (1):



Delta mean subgrid and resolved TKE [m^2/s^2]

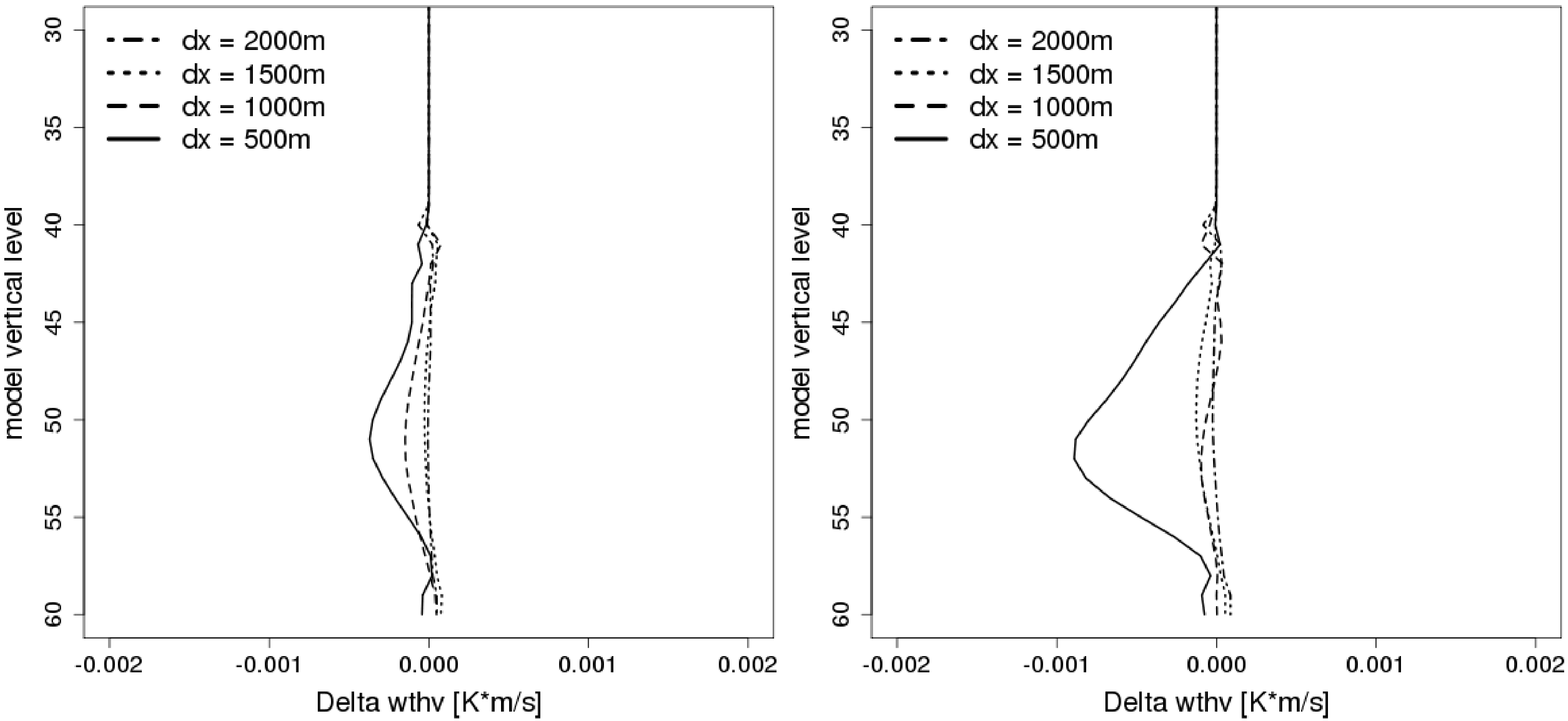
note: the scale Delta TKE of modification (1) was from **-0.2** to **0.2** [m^2/s^2]

Modification (1bis)

Differences from the modification (1):

h = PBL height

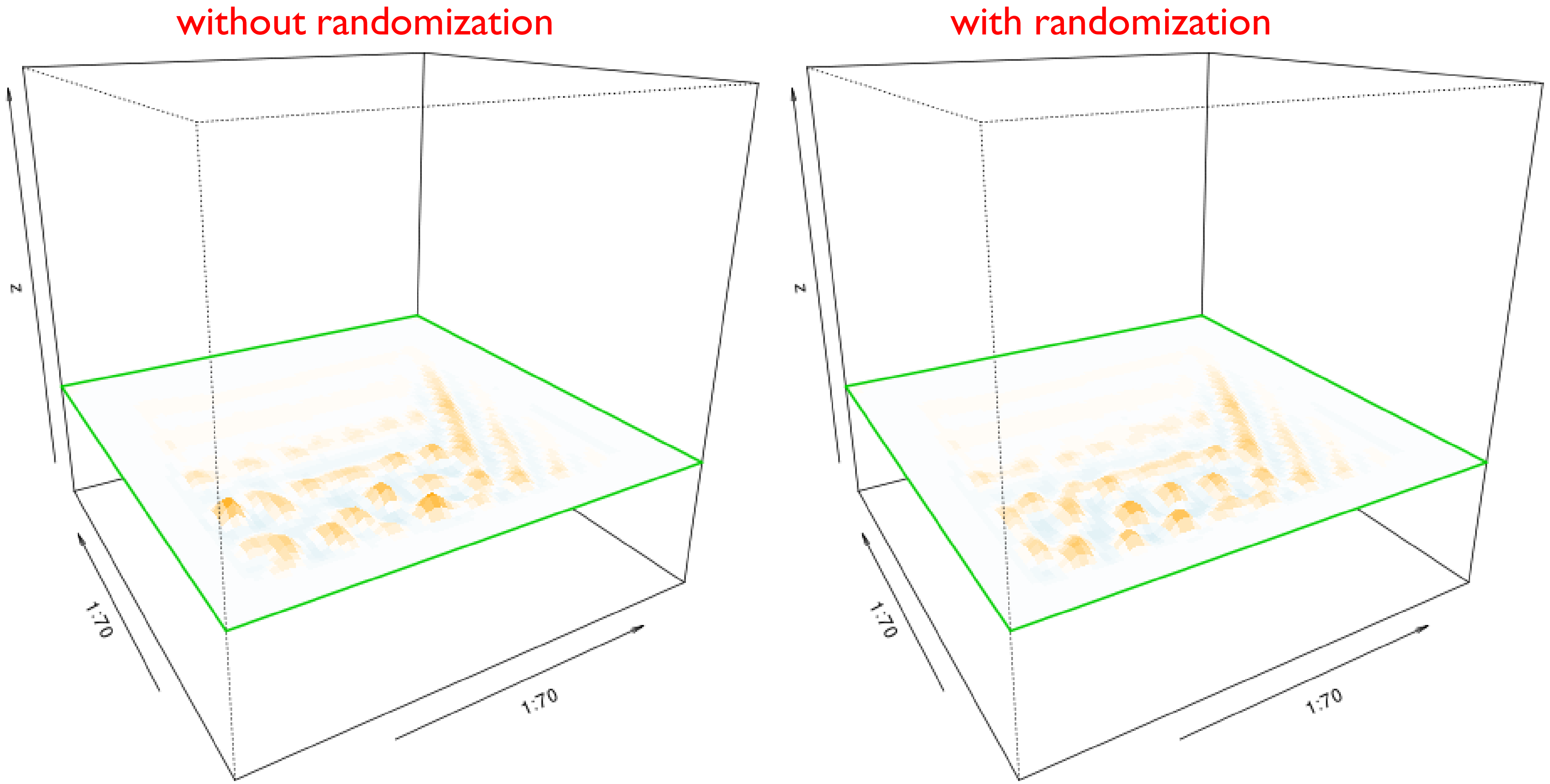
h = L_{BL89}



Delta mean subgrid buoyancy flux [Km/s]

note: the scale Delta wthv of modification (1) was from **-0.02** to **0.02** [m^2/s^2]

Modification (1bis)



Structure of the vertical velocity (blue - downdraft, orange - updraft) fields at the 47. model level of the simulations with EDKF-modification (1), dx=500 m and h = L_{BL89}.

Modification (2)

Decrease subgrid turbulent fluxes

by Boutle at al. (2014)

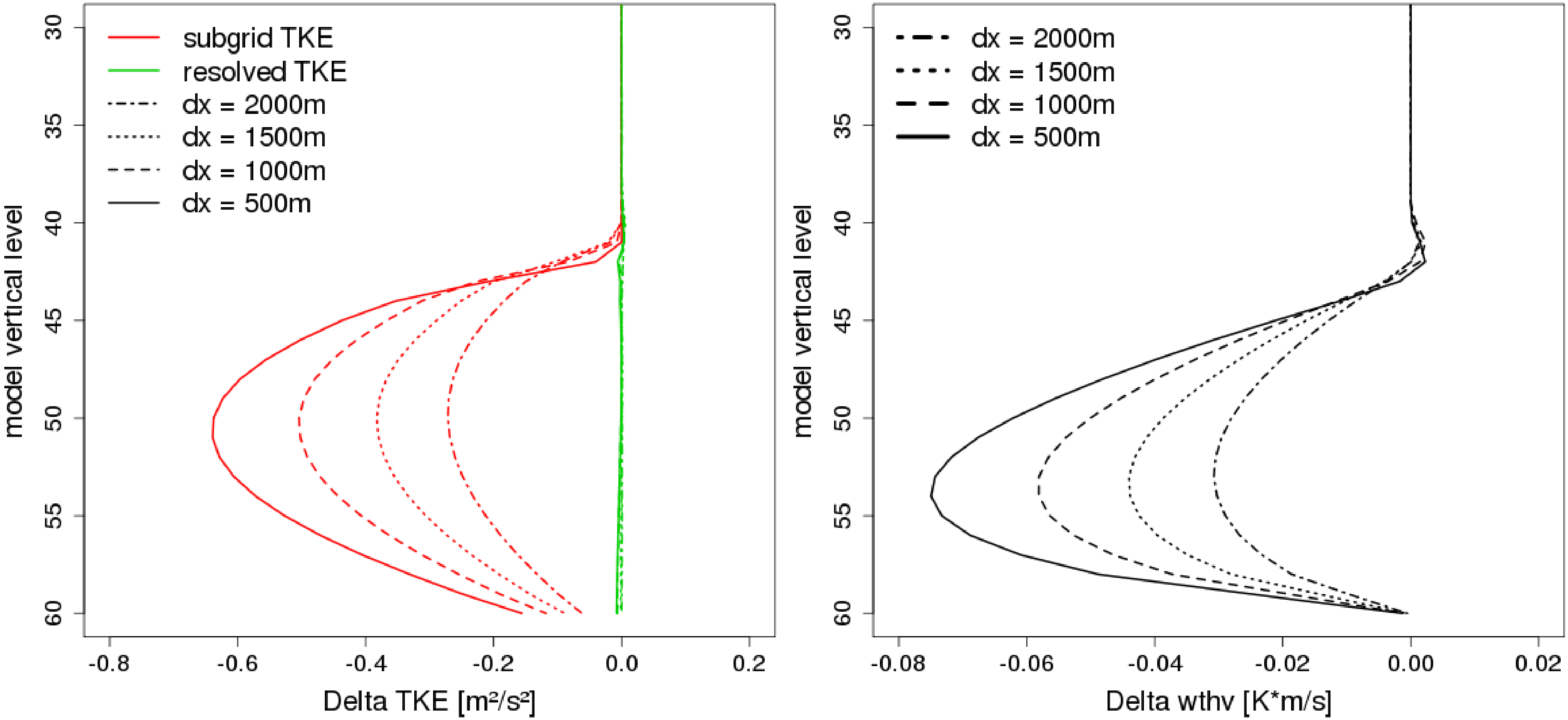
- In Boutle at al. (2014) a simple solution was suggested to decrease the subgrid turbulent fluxes - based on the work of Honnert at al. (2011)
- The subgrid turbulent fluxes are multiplied by the coefficient *ZPLAV* which depends on the normalized resolution:

$$ZPLAV = \frac{X^2 + 0.19 * X^{2/3}}{X^2 + 0.15 * X^{2/3} + 0.33}$$

$$X = \frac{\sqrt{dx * dy}}{L_{BL89}}$$

Modification (2)

Differences from the reference:



Modification (3)

New set of equations for the Mass-Flux paramertization

by Rachel Honnert

$$\overline{w'\theta'_l}_{MF} = M(\theta_{lu} - \overline{\theta_l})\frac{1}{1-\alpha}$$

$$\overline{w'r'_t}_{MF} = M(r_{tu} - \overline{r_t})\frac{1}{1-\alpha}$$

$$\alpha = \frac{M}{w_u - \overline{w}}$$

$$\frac{1}{M}\frac{\partial M}{\partial z} = \varepsilon - \delta$$

$$\frac{1}{2}\frac{\partial (w_u - \overline{w})^2}{\partial z} = -\varepsilon (w_u - \overline{w})^2 \frac{1}{1-\alpha} - (w_u - \overline{w})\frac{\partial \overline{w}}{\partial z} + B_u - \overline{B} - (P_u - \overline{P}) - \frac{1}{\alpha}\frac{\partial \alpha \overline{w'^2}^u}{\partial z}$$

$$B = g \times \frac{\theta_{vu} - \overline{\theta_v}}{\overline{\theta_v}}$$

$$\theta_{vu} = f(\theta_{lu}, r_{tu})$$

$$\frac{\partial \theta_{lu}}{\partial z} = -\varepsilon(\theta_{lu} - \overline{\theta_l})\frac{1}{1-\alpha}$$

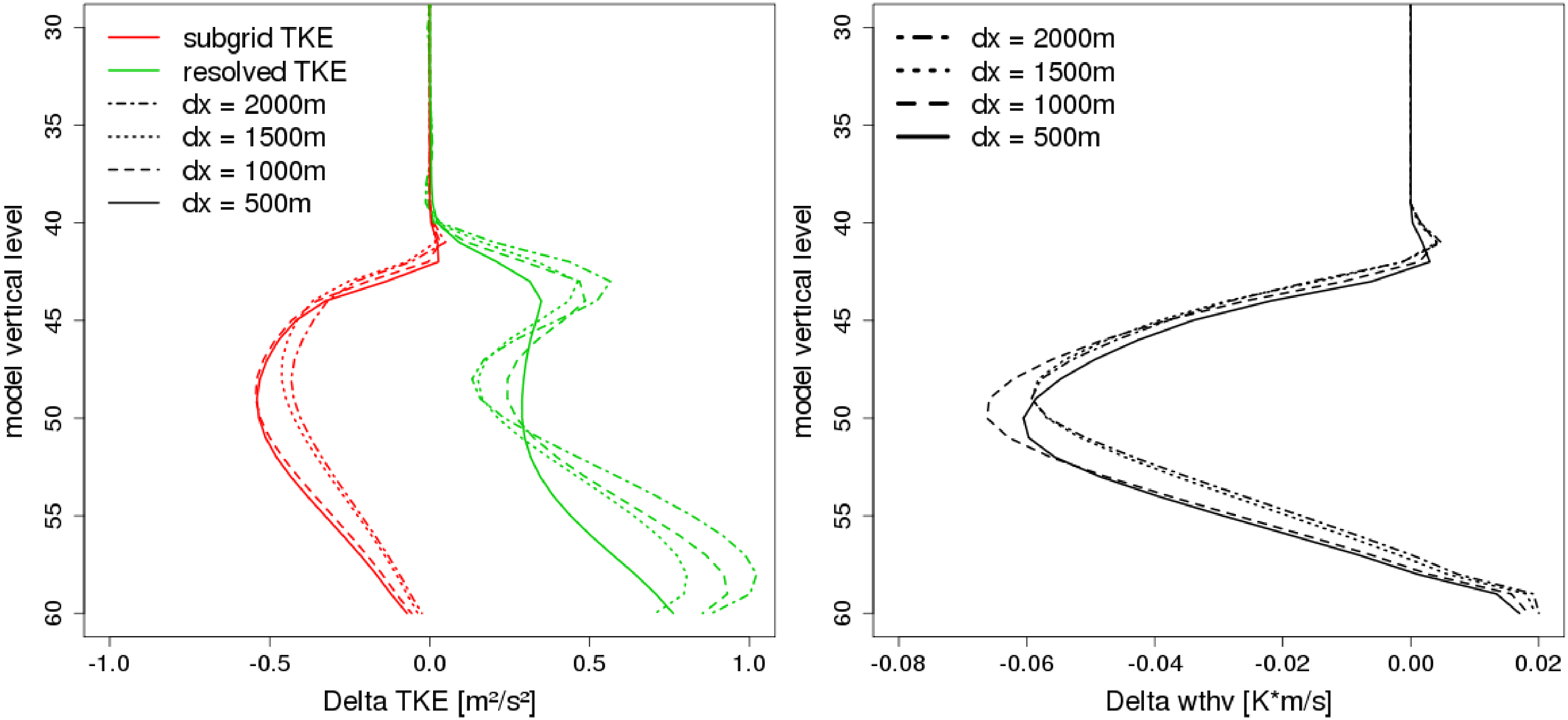
$$\frac{\partial r_{tu}}{\partial z} = -\varepsilon(r_{tu} - \overline{r_l})\frac{1}{1-\alpha}$$

- The new mass-flux equations do not neglect the resolved vertical velocity and the subgrid thermal fraction

θ_l is the liquid potential temperature, r_t is the total water content, θ_v is the virtual potential temperature, α is the thermal area, the overline means the spatial average (with u it means over the thermal area), ε is the entrainment, δ is the detrainment, B_u is the buoyancy and P_u is the pressure

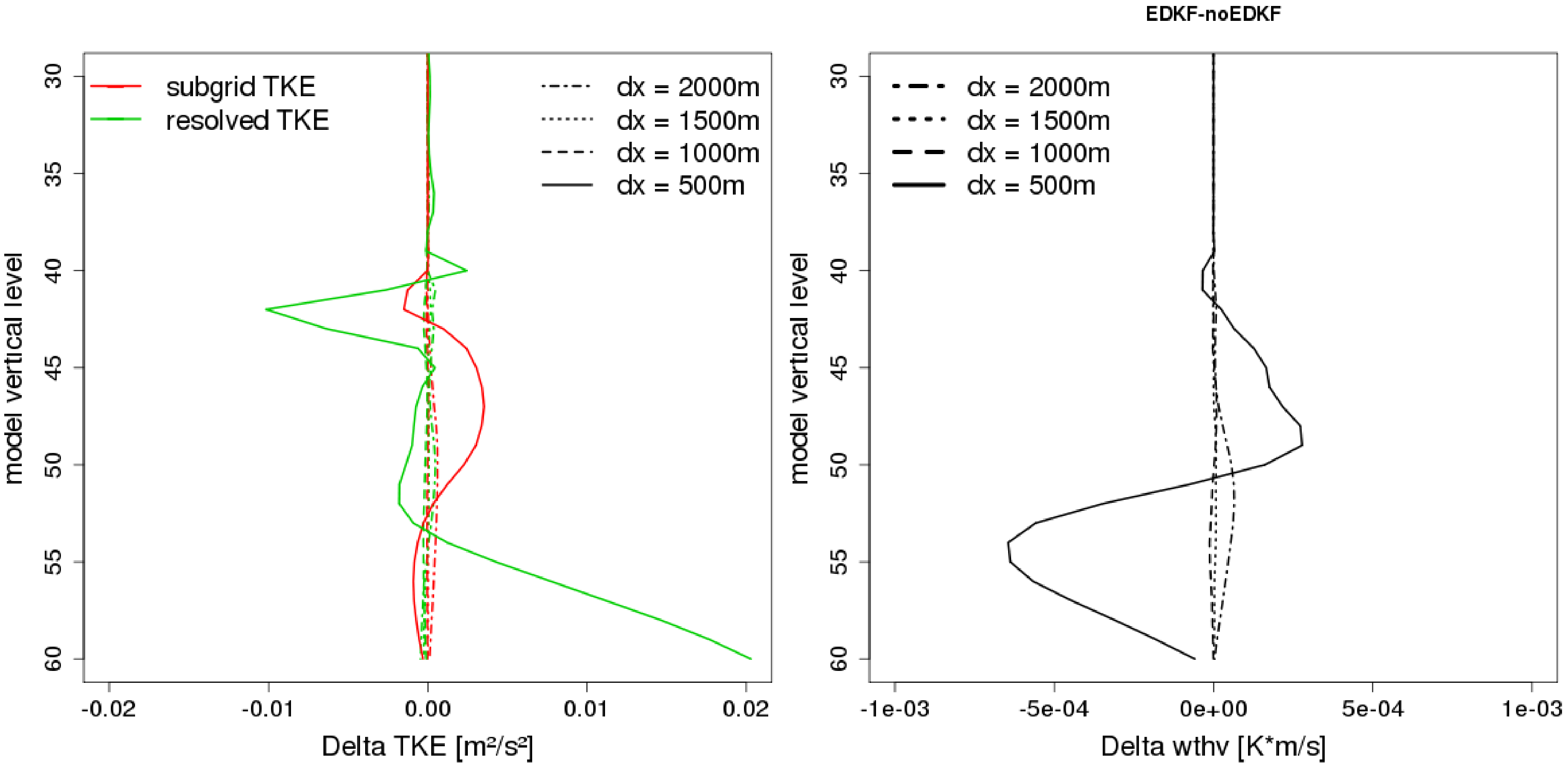
Modification (3)

Differences from the reference:



Modification (3)

Differences from the reference **WITHOUT EDKF:**



Future plans

- Make idealized AROME simulations with ARM case too

- Try modification (1) with an other coefficient value and examine the effect

- Validate modification (1) via LES MesoNH simulations – case IHOP and ARM

- Validate modification (1) via real cases

Thank you for your attention!

References:

BOUTLE, I. A., J. E. J. EYRE and A. P. LOCK, 2014: Seamless Stratocumulus Simulation across the Turbulent Gray Zone. Mon. Wea. Rev., 142, 1655-1668

HONNERT, R., V. MASSON and F. COUVREUX, 2011: A Diagnostic for Evaluating the Representation of Turbulence in Atmospheric Models at the Kilometric Scale. J. Atmos. Sci., 68, 3112-3131

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