Annual Seminar 2022

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Recent developments at Meteo-France in convection parametrization for Global Circulation Models and turbulence-convection interaction for Limited-Area Models

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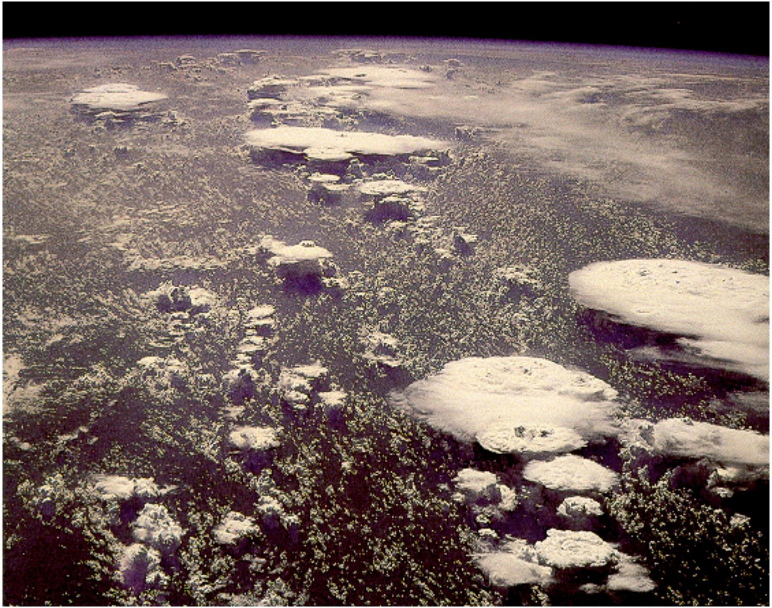
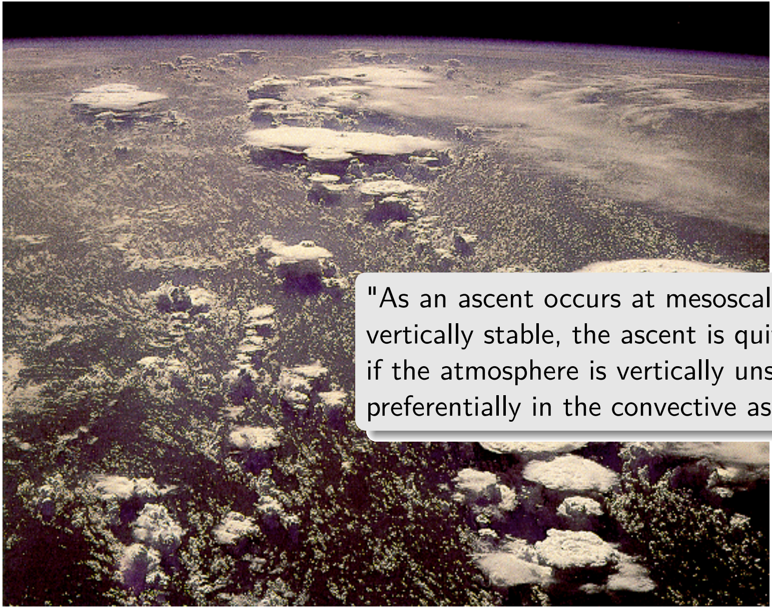
Plan

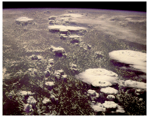
1. **Address the link between mesoscale vertical velocity and convection at microscale (LSM)**
2. **Evaluation and improvement of turbulence parameterization in convective clouds (km scale)**
3. **Improvement of water mass conservation in AROME**



Picture Space Shuttle Challenger



"As an ascent occurs at mesoscale, if the atmosphere is vertically stable, the ascent is quite uniform horizontally, and if the atmosphere is vertically unstable, the ascent occurs preferentially in the convective ascents at microscale."



Implications for parameterization

"As an ascent occurs at mesoscale, if the atmosphere is vertically stable, the ascent is quite uniform horizontally, and if the atmosphere is vertically unstable, the ascent occurs preferentially in the convective ascents at microscale."

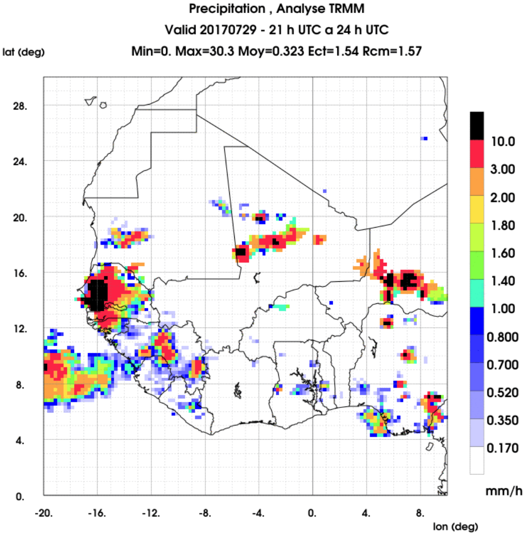
Classical approach: $\alpha_u w_u + (1 - \alpha_u) w_e = 0$

Proposal: define these vertical velocities as absolute ones, $\alpha_u w_u + (1 - \alpha_u) w_e = \overline{w}$

In the convective updraft, vertical velocity has 2 sources : subgrid w_s and resolved-scale $\overline{w}$, this leads to : $w_u = w_s + \gamma\,\overline{w}$, avec $1 < \gamma < \frac{1}{\alpha_u}$.

$F_t - \overline{w}\overline{\psi} = \alpha_u \left[w_s + (\gamma - 1)\overline{w} \right] (\psi_u - \psi_e)$

Resolved w in the PCMT convection parameterization



Situation from 29 July 2017 over Sénégal.

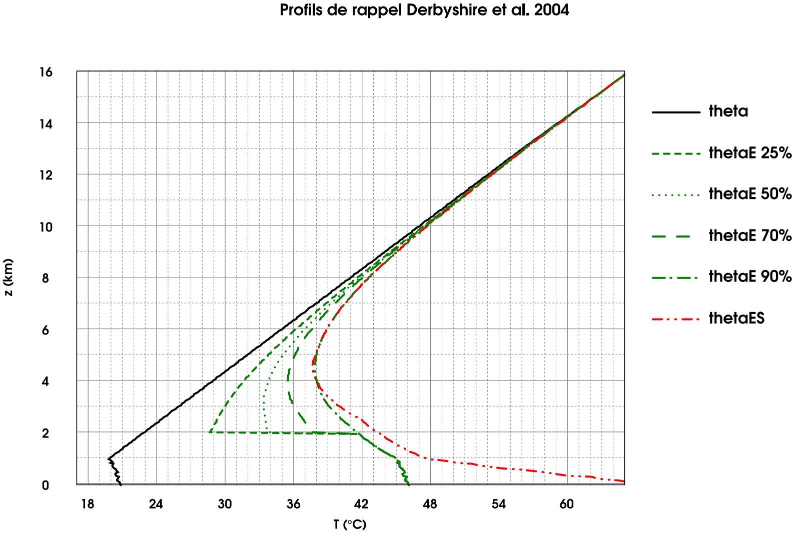
TRMM versus PCMT std : ▸ Lien

TRMM versus PCMT resolved_wu : ▸ Lien

Meso-NH LES simulation

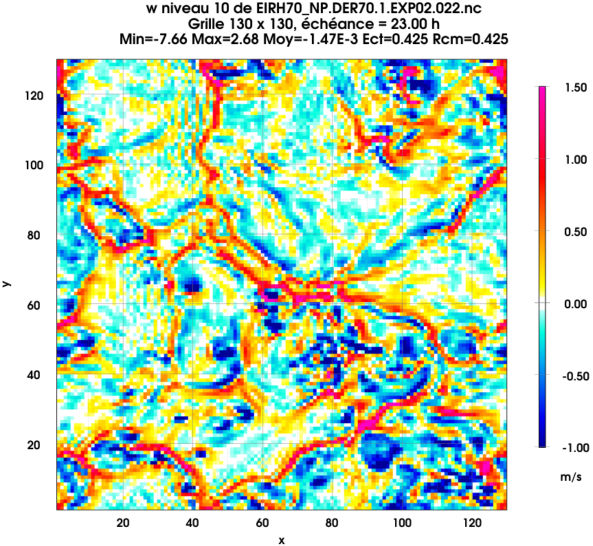
- Meso-NH : 500 *m* resolution, biperiodic, non-hydrostatic, anelastic model.
- Idea : use an idealized case to address the impact of a mesoscale forcing on convection.
- Question: which impact has mesoscale vertical velocity on convection intensity at microscale ?
- Question: which (γ) fraction of the mesoscale ascent occurs in the updrafts at microscale ?
- Quantify the link between this fraction γ and vertical stability.
- $\Rightarrow$ Revisit the Derbyshire et al. 2004 case.

Derbyshire et al. 2004 case



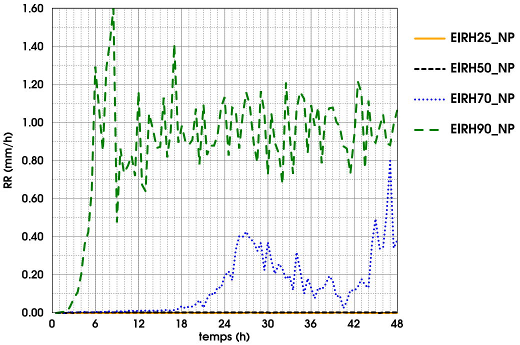
Derbyshire, S. H. and Beau, I. and Bechtold, P. and Grandpeix, J.-Y. and Piriou, J.-M. and Redelsperger, J.-L. and Soares, P. M. M., *Sensitivity of moist convection to environmental humidity*, QJRMS 2004

Meso-NH simulations of the D2004 case

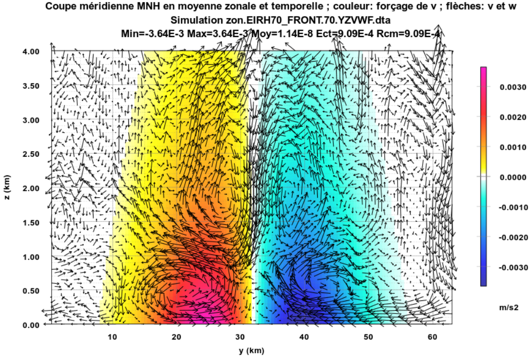


Derbyshire et al. QJRMS 2004 case.

Without mesoscale forcing (EIRH70_NP)



Idealized mesoscale forcing

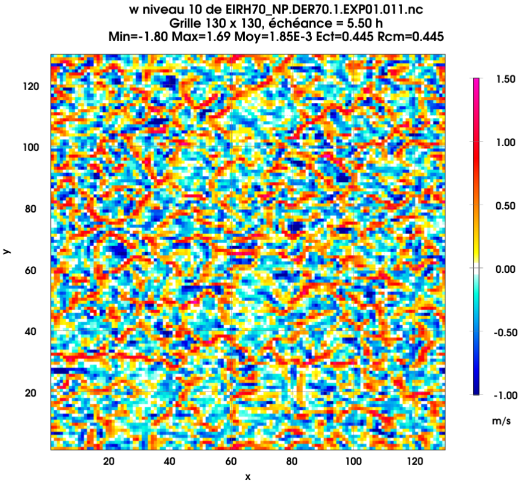


$$\frac{\partial u}{\partial t} = -(\vec{u}\cdot\vec{\nabla})u - \frac{1}{\rho}\frac{\partial p}{\partial x} + \dot{u}_{tur} + \frac{u_t - \overline{u}}{\tau} \quad (1)$$

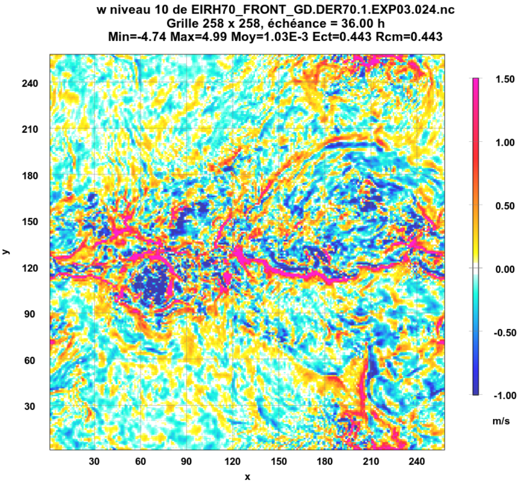
$$\frac{\partial v}{\partial t} = -(\vec{u}\cdot\vec{\nabla})v - \frac{1}{\rho}\frac{\partial p}{\partial y} + \dot{v}_{tur} + \frac{v_t - \overline{v}}{\tau} + \dot{v}_m \quad (2)$$

$$\dot{v}_m = -\gamma_0 \frac{y - \frac{L}{2}}{y_0} \exp[-(\frac{y - \frac{L}{2}}{y_1})^2]\, e^{-z/H} \quad (3)$$

Meso-NH D2004 simulations with forcing

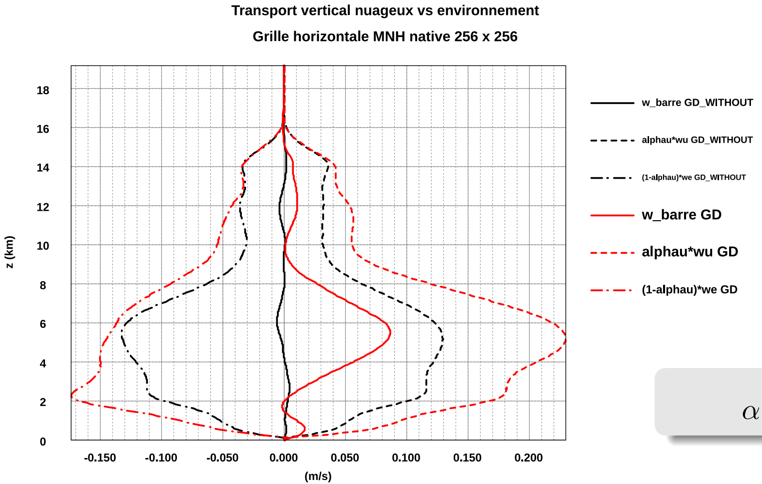


Without forcing



With forcing

Vertical velocity diagnostics, ascending and descending



$$\alpha_u w_u + (1 - \alpha_u) w_e = \overline{w}$$

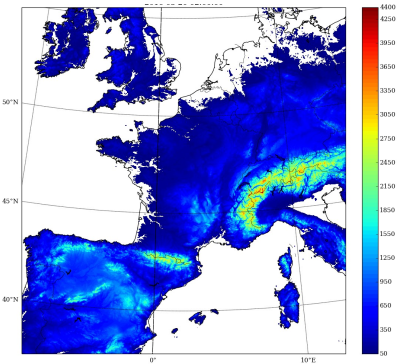
Meso-NH simulation, 70 % rel. hum. case with (red) and without (black) mesoscale forcing

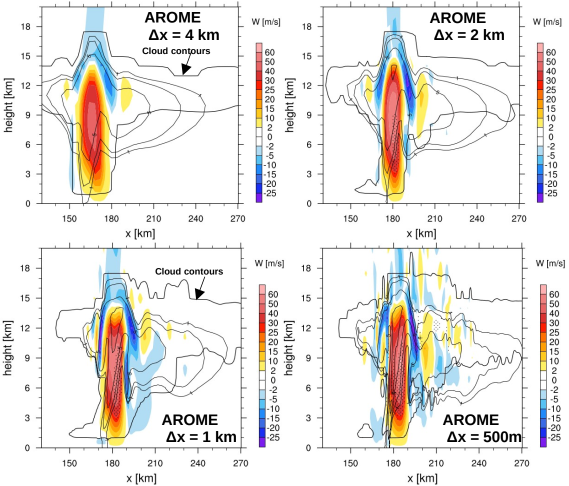
Conclusions / Perspectives

- The link between convective intensity and mesoscale vertical velocity is explored with parameterizations and explicit simulations.
- A significant part of the mesoscale ascent occurs inside convective updrafts ⇒ changes the mass conservation paradigm in convective parameterizations : convection no longer closes the mass budget.
- First ARPEGE tests with the PCMT scheme are encouraging. ⇒ Will be tested in the Tiedtke-Bechtold scheme, which is now the operational convection scheme in ARPEGE.
- Quantitative study of the link between (i) mesoscale forcing (ii) vertical stability ⟺ and convection is under progress ⇒ revisit the Derbyshire et al. 2004 case in adding a mesocale non-convective forcing.
- Synergy between parameterizations and LES studies.

Limited-Area Models for Numerical Weather Prediction

- Explicit representation of convective motions
  - LAM with kilometer-scale resolution (3km – 1 km)
    - COSMO, UKV, HARMONIE, JMA, …
    - At Météo-France: AROME
  - No deep convection scheme
  - Still need a shallow convection scheme





Vertical velocity (m/s)

fully compressible equations, SISL scheme **AROME-France**

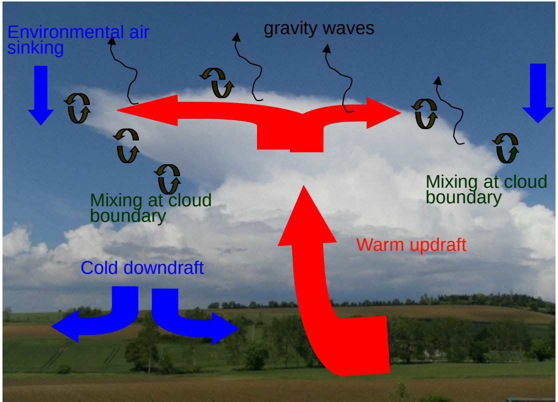
Δx : 2.5 km (since 2008) → Δx : 1.3 km (since 2016)

Interaction betwen convection and turbulence

Turbulence: extensively studied in the atmospheric boundary layer

Convective clouds associated with strong turbulence: instabilities, updraft, downdraft, gravity waves …

- → Idealized Large-Eddy Simulations of deep convection
- → Characterization of turbulence inside convective clouds, not enough subgrid turbulence *Verrelle, Ricard, Lac, 2015, 2017 QJRMS*
- → Objective: Evaluation and improvement of turbulence parameterization in Cloud-Permitting Models o(1km)



LES of deep convective clouds

Configuration with Meso-NH:

1.5 order 3D turbulence scheme: prognostic TKE (*Cuxart et al, 2000*) with Deardorff mixing length

One-moment microphysical scheme: ICE3 (ice, cloud, rain, graupel, snow)

Lac et al 2018 GMD

$$\frac{\partial e}{\partial t} = -\frac{1}{\rho_{dref}}\frac{\partial(\rho_{dref} e \overline{u_i})}{\partial x_j} \boxed{-\overline{u_i' u_j'}\frac{\partial \overline{u_i}}{\partial x_j}} + \boxed{\frac{g}{\theta_{vref}}\overline{u_3' \theta_v'}} + \frac{1}{\rho_{dref}}\frac{\partial}{\partial x_j}\left(C_T \rho_{dref} L e^{1/2}\frac{\partial e}{\partial x_j}\right) \boxed{- C_\epsilon \frac{e^{3/2}}{L}}$$

Dynamical production

Thermal production

Dissipation

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Initial conditions:

Unstable conditions from:
(Weisman and Klemp, 1982)
Moderate wind shear

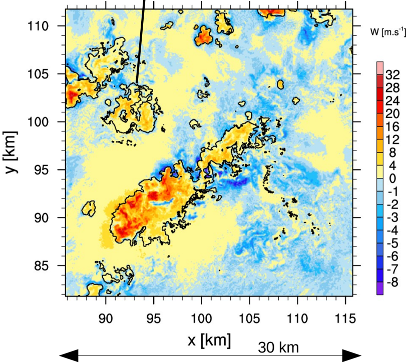
$$\frac{\partial e}{\partial t} = -\frac{1}{\rho_{dref}}\frac{\partial(\rho_{dref}e\overline{u_i})}{\partial x_j}\boxed{-\overline{u'_i u'_j}\frac{\partial \overline{u_i}}{\partial x_j}}+\boxed{\frac{g}{\theta_{vref}}\overline{u'_3\theta'_v}}+\frac{1}{\rho_{dref}}\frac{\partial}{\partial x_j}\left(C_T\rho_{dref}Le^{1/2}\frac{\partial e}{\partial x_j}\right)\boxed{-C_\epsilon\frac{e^{3/2}}{L}}$$

Dynamical production

Thermal production

Dissipation

Cloud contour (ri + rc > 0.001 g/kg)



LES: Δx = Δy = Δz = 50 m

Verrelle, Ricard, Lac 2017 MWR

Horizontal cross sections of vertical velocity (m/s) at 6 km AGL t=175 min

LES of deep convective clouds

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1.5 order 3D turbulence scheme: prognostic TKE (*Cuxart et al, 2000*) with Deardorff mixing length

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Meso-NH
mesoscale non-hydrostatic model

Lac et al 2018 GMD

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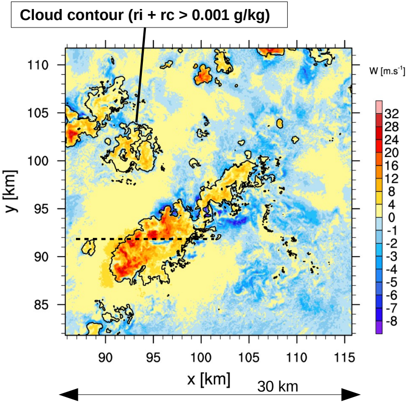
Dynamical production

Thermal production

Dissipation



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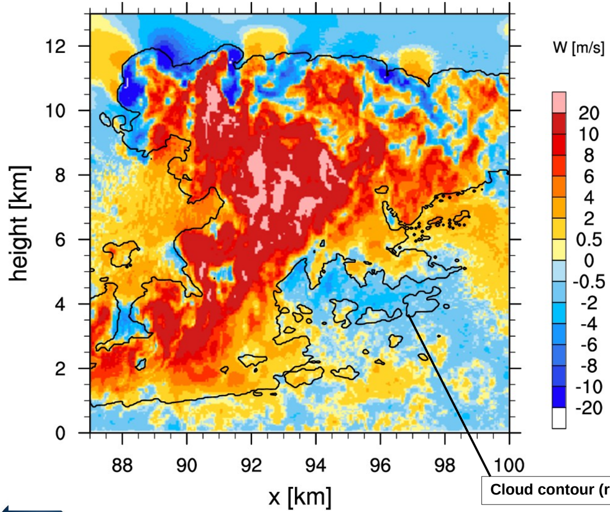
Horizontal cross sections of vertical velocity (m/s) at 6 km AGL t=175 min

cnrs

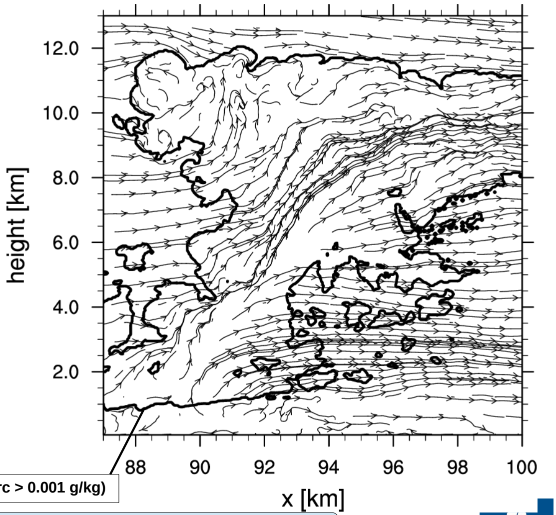
METEO FRANCE

LES of deep convective clouds Δx = 50 m

Vertical cross sections of vertical velocity (m/s) t=175 min



Streamlines t = 175 min



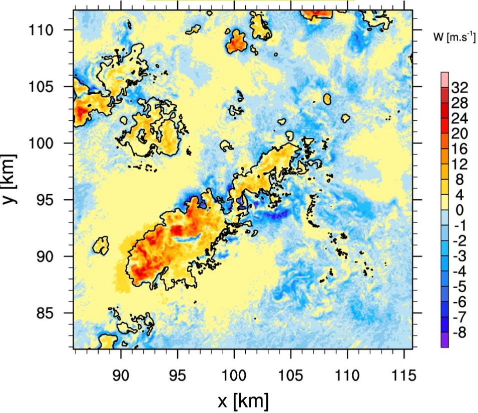
Cloud contour (ri + rc > 0.001 g/kg)

→ well developed cumulonimbus with a strong updraft and many eddies

Characterization of turbulence inside convective clouds

- LES: reference simulation (50-m grid spacing)

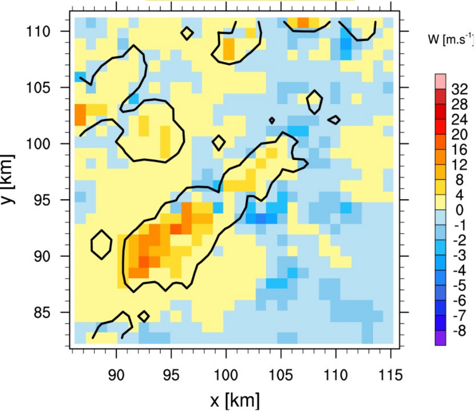
LES field: w (50 m)



Characterization of turbulence inside convective clouds

- LES: reference simulation (50-m grid spacing)
- Computation of reference fields at coarser resolutions **Δx** (**500m, 1 km, 2 km**) by averaging LES fields
- Mean filtering by boxes of size **Δx** *(Honnert et al. 2011, Shin and Hong, 2013, Moeng 2014 …)*

Filtered field: $\overline{w}^{\Delta x=1km}$



Computation of terms at Δx:

$$\overline{u}^{\Delta_x}, \overline{v}^{\Delta_x}, \overline{w}^{\Delta_x}, \overline{r_{np}}^{\Delta_x}, \overline{\theta_l}^{\Delta_x}, \ldots$$

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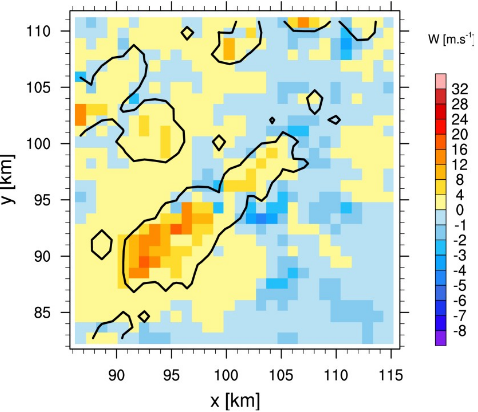

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$$\overline{u}^{\Delta_x}, \overline{v}^{\Delta_x}, \overline{w}^{\Delta_x}, \overline{r_{np}}^{\Delta_x}, \overline{\theta_l}^{\Delta_x}, \dots$$

$$u_i' = (u_i - \overline{u_i}^{\Delta_x})$$

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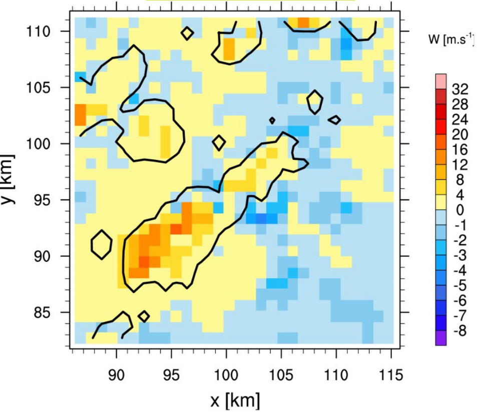


Computation of terms at Δx:

$$\overline{u}^{\Delta_x}, \overline{v}^{\Delta_x}, \overline{w}^{\Delta_x}, \overline{r_{np}}^{\Delta_x}, \overline{\theta_l}^{\Delta_x}, \ldots$$

$$u'_i = (u_i - \overline{u_i}^{\Delta_x})$$

Computation of subgrid terms at Δx:

Turbulent fluxes:

$$\overline{u'_i u'_j}^{\Delta_x} = \overline{(u_i - \overline{u_i}^{\Delta_x})(u_j - \overline{u_j}^{\Delta_x})}^{\Delta_x} + \overline{f^{u'_i u'_j}}^{\Delta_x}$$

Variances:

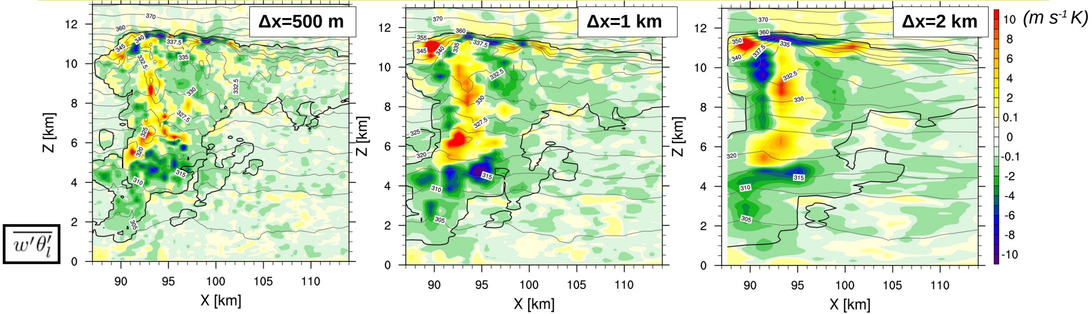
$$\overline{u'^2}^{\Delta_x}, \overline{v'^2}^{\Delta_x}, \overline{w'^2}^{\Delta_x}, \overline{r'^2_{np}}^{\Delta_x}, \overline{\theta'^2_l}^{\Delta_x}, \ldots$$

Subgrid TKE:

$$\overline{e}^{\Delta_x}_{ref} = \frac{1}{2}(\overline{u'^2}^{\Delta_x} + \overline{v'^2}^{\Delta_x} + \overline{w'^2}^{\Delta_x})$$

Characterization of turbulence inside convective clouds

Vertical cross sections: vertical heat flux computed from the LES at different Δx (500 m, 1 km and 2 km) at t=175 min



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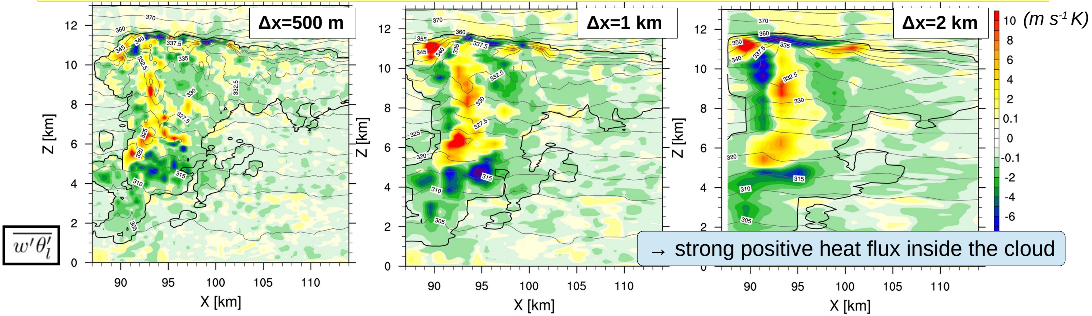

→ strong positive heat flux inside the cloud

Characterization of turbulence inside convective clouds

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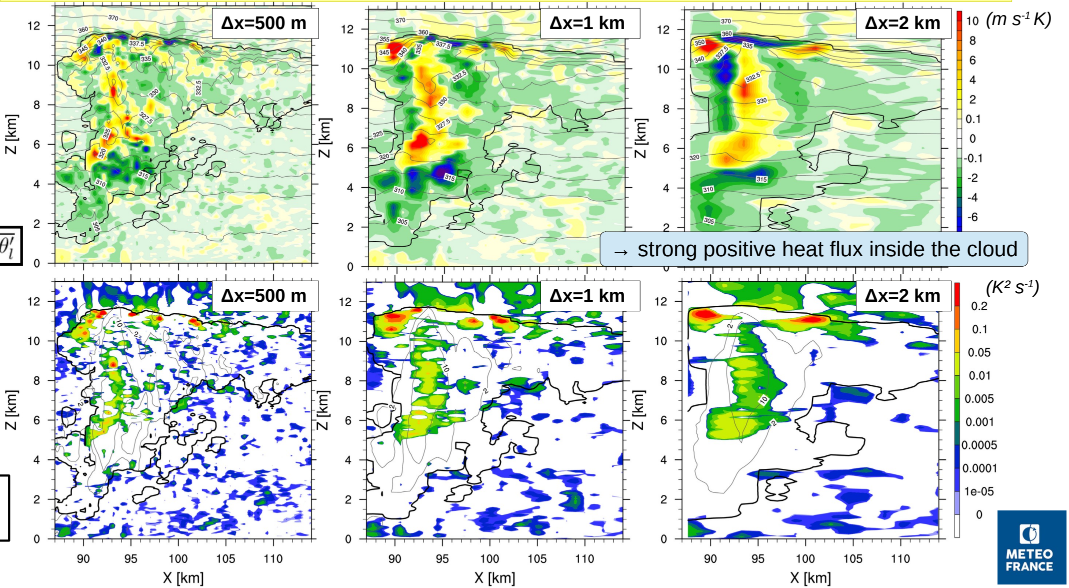

$\overline{w'\theta_l'}$

→ strong positive heat flux inside the cloud

$\overline{w'\theta_l'} * \frac{\partial\overline{\theta_l}}{\partial z}$

Characterization of turbulence inside convective clouds

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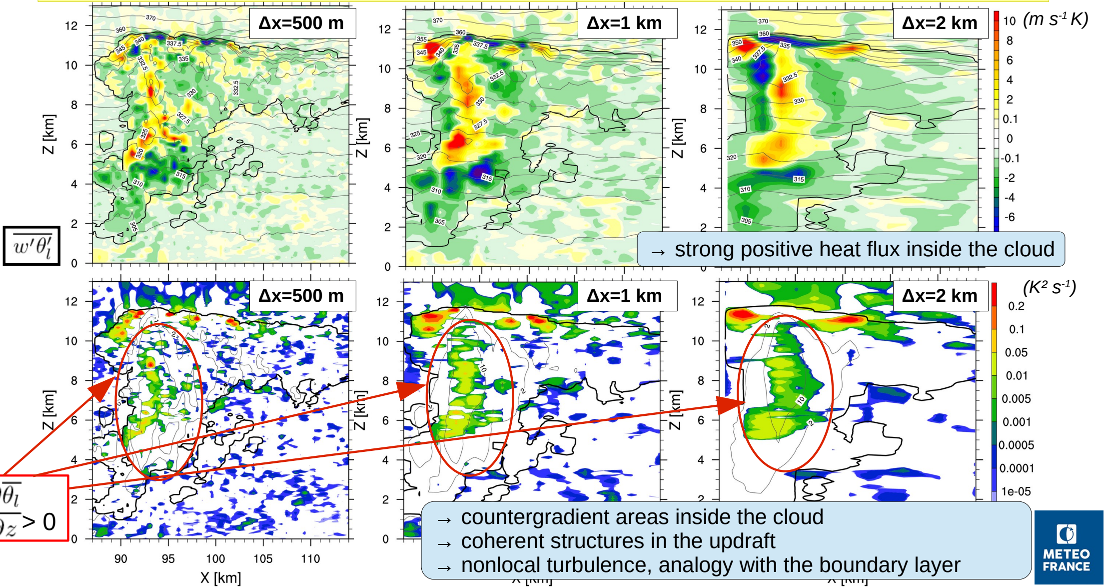

$\overline{w'\theta_l'}$

→ strong positive heat flux inside the cloud

$$\overline{w'\theta_l'} * \frac{\partial \overline{\theta_l}}{\partial z} > 0$$

- → countergradient areas inside the cloud
- → coherent structures in the updraft
- → nonlocal turbulence, analogy with the boundary layer

Evaluation of turbulence parameterizations

Off-line evaluation: computation of parameterized fluxes from the LES at Δx → $\overline{w'\theta_l'}$

Kgrad

Cuxart et al, 2000
CBR scheme

$$\overline{w'\theta_l'}^{\Delta_x} = -\frac{2}{3C_{p\theta}}\overline{\phi_i}^{\Delta_x} L\sqrt{\overline{e}_{ref}^{\Delta_x}}\,\frac{\partial\overline{\theta_l}^{\Delta_x}}{\partial z}$$

L mixing length of *Bougeault-Lacarrere 1989*

based on K gradient: $\overline{w'\theta_l'} = -K\frac{\partial\overline{\theta_l}}{\partial z}$

Evaluation of turbulence parameterizations

Off-line evaluation: computation of parameterized fluxes from the LES at Δx → $\overline{w'\theta_l'}$

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L mixing length of *Bougeault-Lacarrere 1989*

based on K gradient: $\overline{w'\theta_l'} = -K\frac{\partial\overline{\theta_l}}{\partial z}$

Hgrad

Moeng et al, 2010

$$\overline{w'\theta_l'}^{\Delta_x} = C_{\Delta_x}\left(\frac{\partial\overline{w}^{\Delta_x}}{\partial x}\frac{\partial\overline{\theta_l}^{\Delta_x}}{\partial x} + \frac{\partial\overline{w}^{\Delta_x}}{\partial y}\frac{\partial\overline{\theta_l}^{\Delta_x}}{\partial y}\right)$$

based on product of horizontal gradients: $\overline{w'\theta_l'} = C\left(\frac{\partial\overline{w}}{\partial x}\frac{\partial\overline{\theta_l}}{\partial x} + \frac{\partial\overline{w}}{\partial y}\frac{\partial\overline{\theta_l}}{\partial y}\right)$

related to a mass flux *(Moeng, 2014), Leonard terms*

Evaluation of turbulence parameterizations

Off-line evaluation: computation of parameterized fluxes from the LES at Δx → $\overline{w'r'_{np}}$

Kgrad

Cuxart et al, 2000
CBR scheme

$$\overline{w'r'_{np}}^{\Delta_x} = -\frac{2}{3C_{pr}}\overline{\phi_i}^{\Delta_x} L\sqrt{\overline{e}^{\Delta_x}_{ref}}\frac{\partial\overline{r_{np}}^{\Delta_x}}{\partial z}$$

L mixing length of *Bougeault-Lacarrere 1989*

based on K gradient: $\overline{w'r'_{np}} = -K\frac{\partial\overline{r_{np}}}{\partial z}$

Hgrad

Moeng et al, 2010

$$\overline{w'r'_{np}}^{\Delta_x} = C_{\Delta_x}\left(\frac{\partial\overline{w}^{\Delta_x}}{\partial x}\frac{\partial\overline{r_{np}}^{\Delta_x}}{\partial x} + \frac{\partial\overline{w}^{\Delta_x}}{\partial y}\frac{\partial\overline{r_{np}}^{\Delta_x}}{\partial y}\right)$$

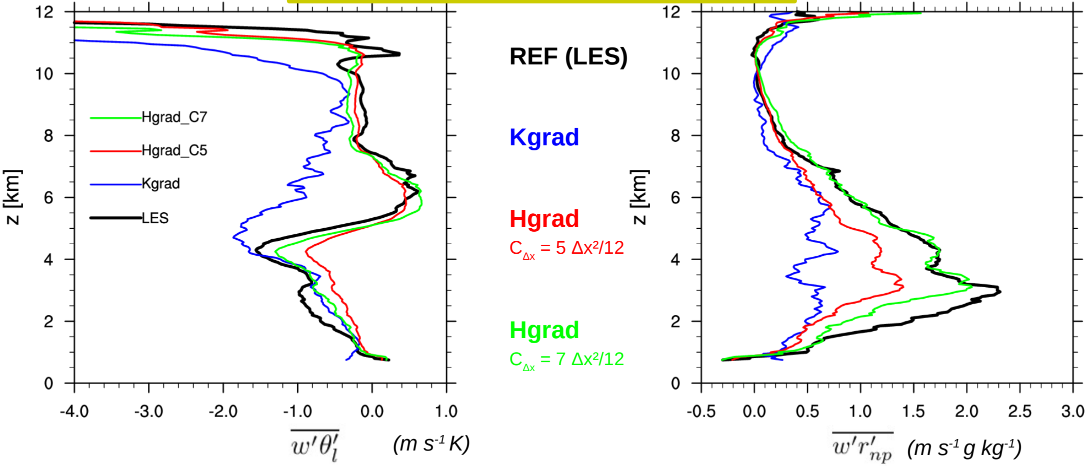
based on product of horizontal gradients: $\overline{w'r'_{np}} = C\left(\frac{\partial\overline{w}}{\partial x}\frac{\partial\overline{r_{np}}}{\partial x} + \frac{\partial\overline{w}}{\partial y}\frac{\partial\overline{r_{np}}}{\partial y}\right)$

related to a mass flux *(Moeng, 2014), Leonard terms*

Evaluation of turbulence parameterizations

→ Off-line evaluation: using LES fields at Δx = 1 km (*Verrelle, Ricard, Lac, 2017 MWR)*

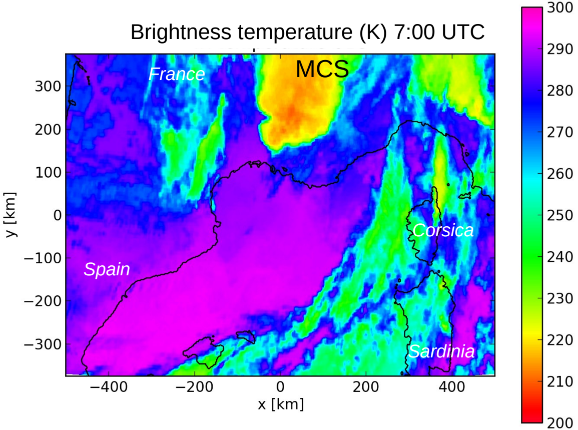
Mean vertical profiles inside convective clouds at t=175 min

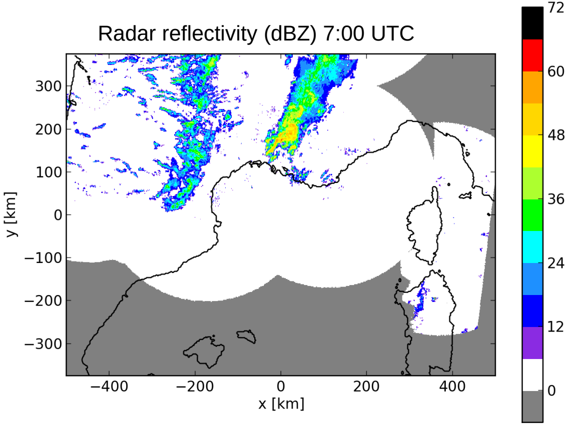


→ **Kgrad** underestimates these two fluxes compared to **REF**
→ **Hgrad** increases these two fluxes and represents the positive heat flux in mid-troposphere

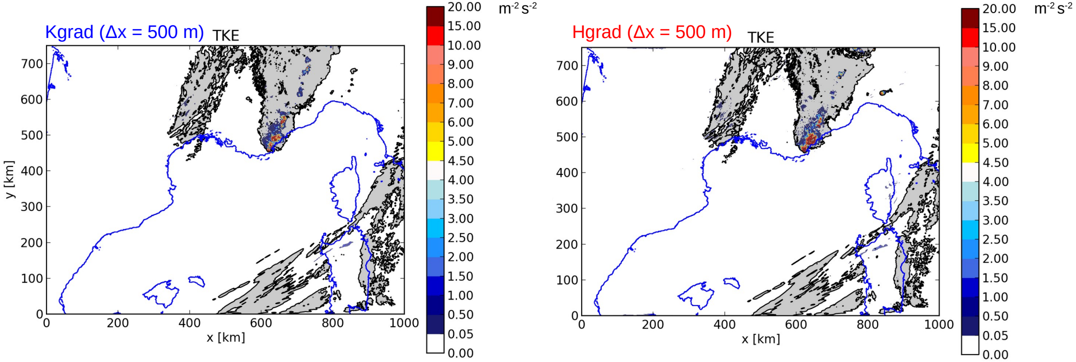
Evaluation on real cases: HyMeX campaign over the Mediterranean area

- Evaluation on IOP6 (24 September 2012)
  - convective system: triggering over the Massif Central
  - a convective line develops, fastly moving eastward
  - heavy rainfall over the Massif Central and South Alps (more than 150 mm/24h)



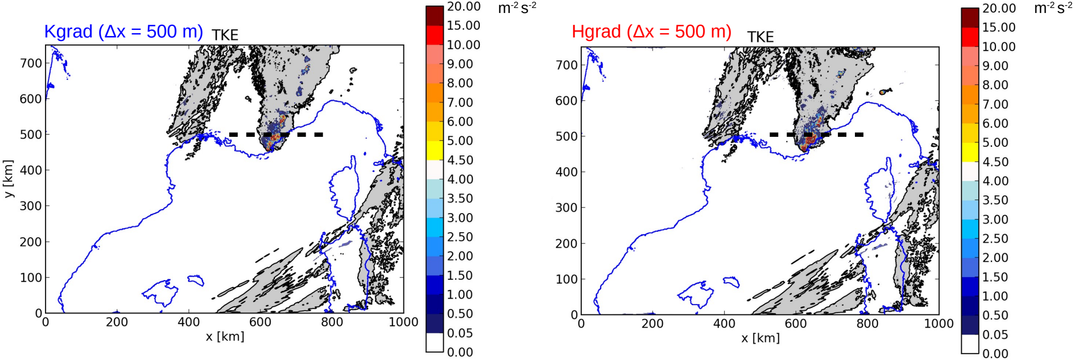


Turbulence inside convective systems



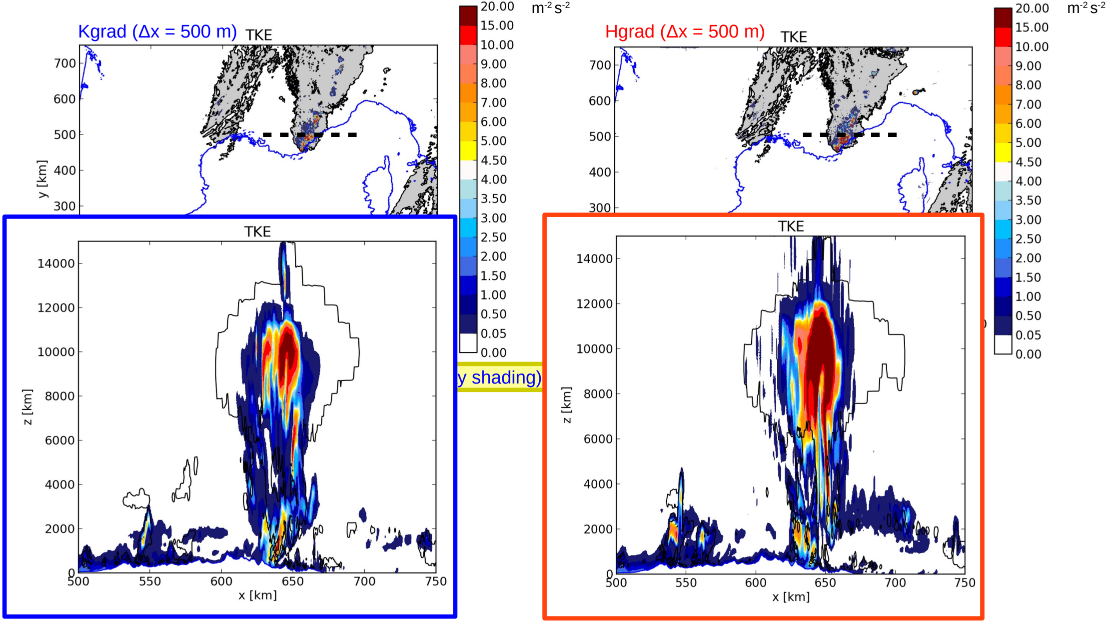
Subgrid TKE and cloud (gray shading) at 8000 m AGL - 10 UTC (24 September 2012)

Turbulence inside convective systems



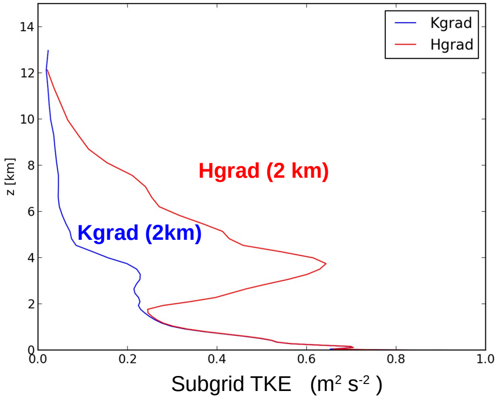
Subgrid TKE and cloud (gray shading) at 8000 m AGL - 10 UTC (24 September 2012)

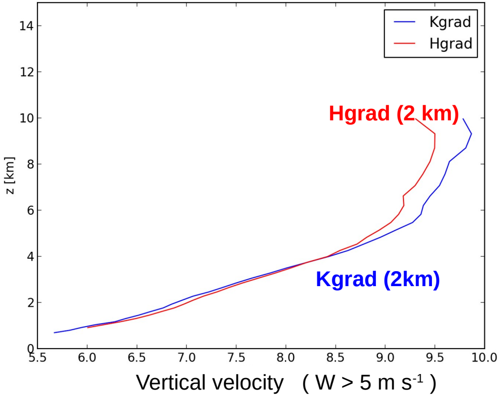
Turbulence inside convective systems



Turbulence and vertical velocity inside convective systems

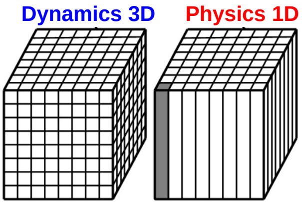
Mean vertical profiles inside convective clouds between 21UTC 23 September and 10 UTC 24 September 2012





→ more subgrid TKE with the **Hgrad run** compared to the **Kgrad run**
→ less intense vertical velocity in updraft cores (W > 5 m/s)
→ better balance between resolved and subgrid parts

Implementation and test in AROME



Gallego, Ricard, Honnert … 2022

Difficulties:

1/ computation of horizontal gradients

- 1D physics
- Computation of in the dynamical part → physics

Honnert and El Khatib, 2020

- Different variables between dynamics (from ARPEGE/ALADIN) and physics (from Meso-NH)

u, v, $d4$, T, q_v, q_i, q_c, q_r, q_s, q_g, P
vertical coordinate: η

u, v, w, θ, r_v, r_i, r_c, r_r, r_s,r_g, TKE
vertical coordinate: z

→ Change of variables:

$$\nabla_h q_x,\ \nabla_h T,\ \nabla_h P \rightarrow \nabla_h r_x,\ \nabla_h \theta$$

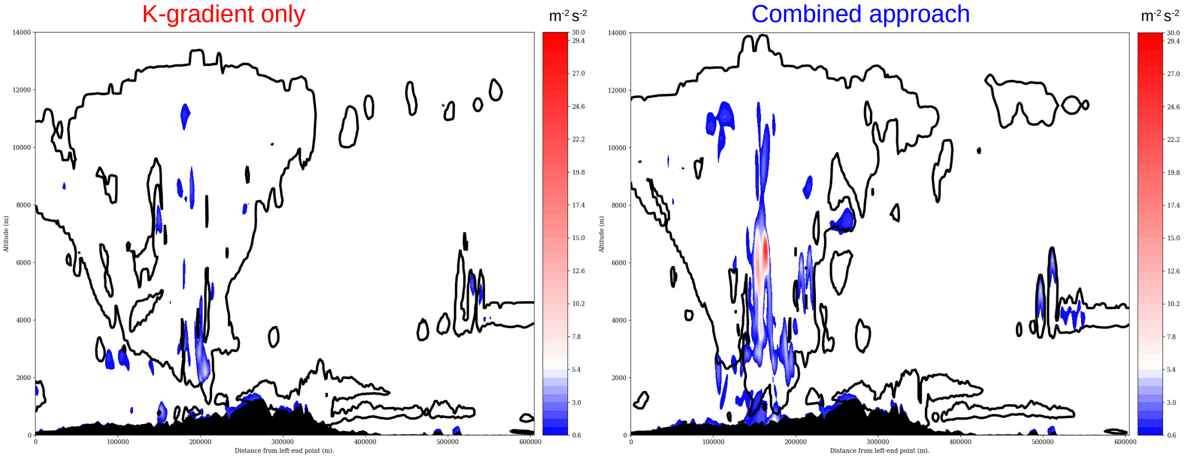
$$\frac{\partial}{\partial x}\Big|_\eta,\ \frac{\partial}{\partial y}\Big|_\eta \rightarrow \frac{\partial}{\partial x}\Big|_z,\ \frac{\partial}{\partial y}\Big|_z$$

2/ Stability problem
→ combined approach:

K-gradient term **Leonard term (Hgrad)**

$$\frac{s^{n+1}-s^n}{\Delta t} = -\frac{\partial}{\partial z}\left(-K\frac{\partial s^{n+1}}{\partial z}\right) - \frac{K_L(\Delta x)^2}{12}\frac{\partial}{\partial z}\left(\frac{\partial w}{\partial x}\frac{\partial s^n}{\partial x} + \frac{\partial w}{\partial y}\frac{\partial s^n}{\partial y}\right)$$

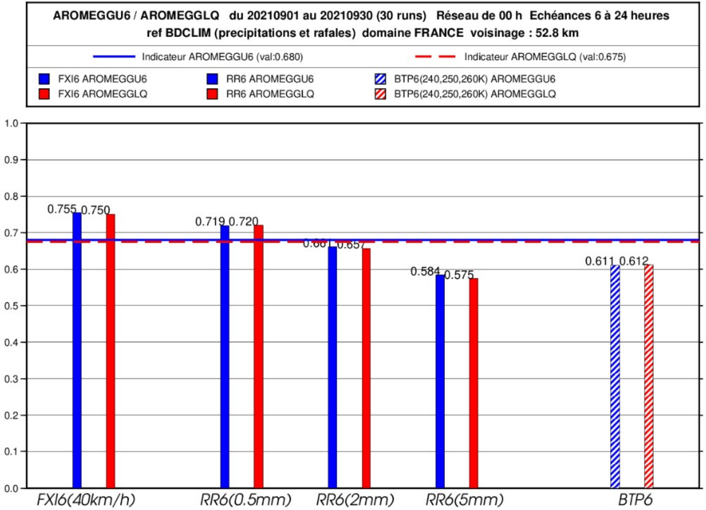
Evaluation with AROME: turbulence inside the clouds over SE France



Vertical cross section: subgrid TKE (shading) and cloud contours - 20 UTC (25 September 2021)

→ more subgrid TKE with the **Leonard terms** run (combined approach) compared to the **K-grad run**

Evaluation with AROME: fuzzy scores over 1 – 30 September 2021



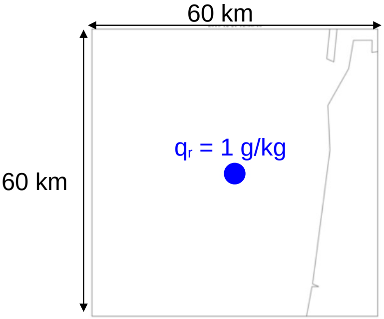
→ slight better scores for wind gust and precipitation for the combined approach compared to K-gradient

Semi-academic 3D AROME tests to verify mass conservation

- Small domain: 48x48x90 points @1250m, setup and coupled with AROME-oper
- Start with $q_c=q_i=q_r=q_s=q_g=0$ except in (24,24,2000m) : q_r=1g/kg
- Microphysics off except sedimentation.
- Turbulence and shallow convection off.
- Forecast term = 40 time steps (dt=50s)

- Flat domain (Z_s=0 m)

- T=280K, U = V = 2 m/s
- Hydrostatic dynamics



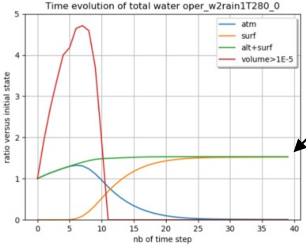
Seity and colleagues 2021

Semi-academic 3D AROME tests to verify mass conservation

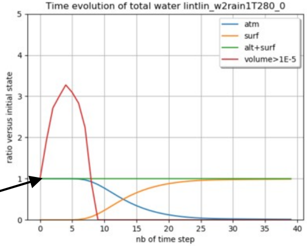
QM cubic SL interpolators

linear SL interpolators

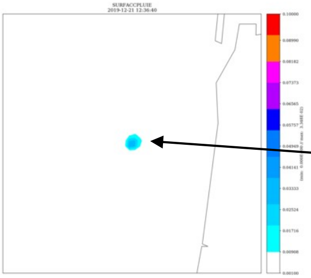
Seity and colleagues 2021



Total water: +50 %
(not so extreme if initialisation on N > 1 points, in real oper cases, partly compensated by numerical diffusion)

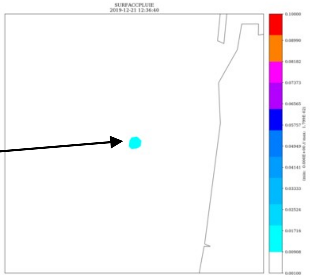


mass conservation

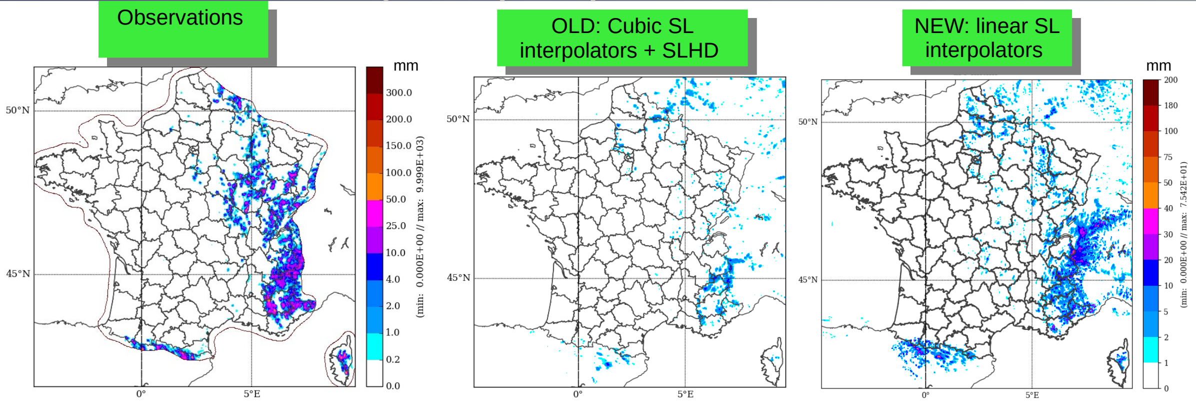


Cumulated surface rain (mm)

→ Problem in mass conservation fixed by changing Semi-Lagrangian interpolators



Test on real case: 25 July 2018 (RR24)



Observations

OLD: Cubic SL interpolators + SLHD

NEW: linear SL interpolators

Seity and colleagues 2021

- New version:
  - Improvement of rain forecasts in diurnal convection cases
  - No longer nessary to use Semi-Lagrangian Horizontal Diffusion (SLHD) on hydrometeors
  - Operational in AROME since last June with equivalent global scores and a better representation of diurnal convection

Conclusion

- Characterization of turbulence from reference LES
  - strong subgrid TKE inside convective clouds
  - countergradient areas for turbulent fluxes due to coherent structures → nonlocal turbulence
- Off-line and online evaluations of turbulence parameterizations inside convective clouds
  - K-gradient formulations not suitable: too weak subgrid TKE and too strong vertical velocity

    Verrelle, Ricard, and Lac, 2015 Quart. J. Roy. Meteor. Soc.
  - better representation with a parameterization based on horizontal gradients *(Moeng et al, 2010)*
    - better vertical turbulent fluxes of heat and water mixing ratio
    - better balance between subgrid and resolved parts

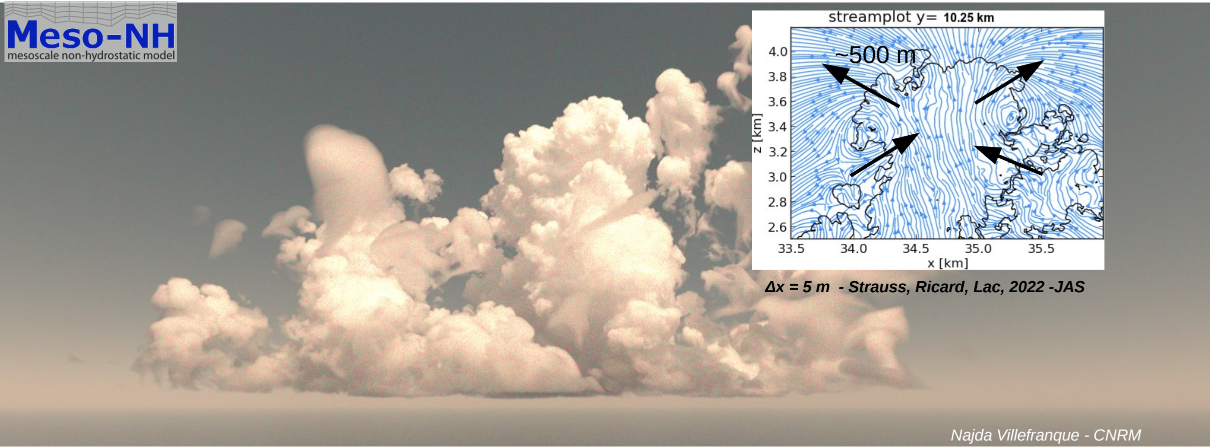
    Verrelle, Ricard, and Lac, 2017 Mon. Wea. Rev. *Strauss, Ricard, Lac, Verrelle, 2019 Quart. J. Roy. Meteor. Soc.*
- Online evaluation of a new turbulence scheme on real cases of deep convection

  → evaluation on longer periods with scores and case studies in AROME

  → first step towards a 3D turbulence scheme in AROME

  → need for fine-scale observations of turbulence inside convective cloud
- Mixing (turbulence and numerical diffusion) can be important also to improve QPFs

Conclusion



Δx = 5 m - Strauss, Ricard, Lac, 2022 -JAS

Najda Villefranque - CNRM

Thank you for your attention!

LES of deep convective clouds

Configuration with Meso-NH:

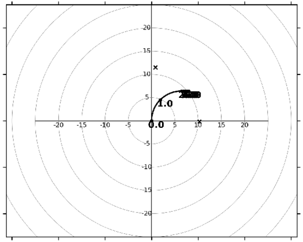
- 1.5 order 3D turbulence scheme: prognostic TKE (*Cuxart et al, 2000*) with the Deardorff mixing length
- One-moment microphysical scheme: ICE3 (ice, cloud, rain, graupel, snow)
- No radiation scheme
- No Coriolis force

Lac et al 2018 GMD

Initial conditions:

- Unstable atmosphere (Weisman and Klemp, 1982)
- Moderate wind shear

Hodograph U, V ($m.s^{-1}$)



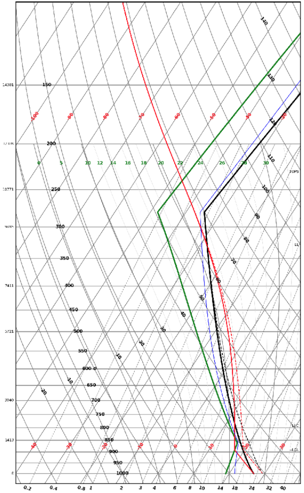
Skew-T Log-P diagram

Tropopause:
RH = 25 %
Linear decrease from the surface

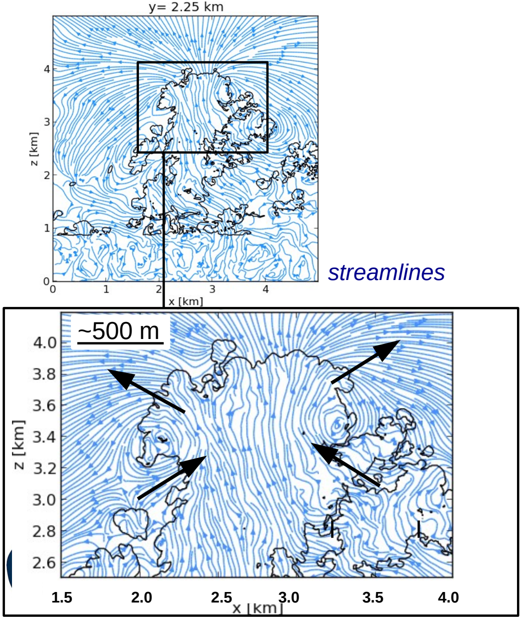
Boundary layer :
r_v = 16g/kg

CAPE ~ 2800 J/kg

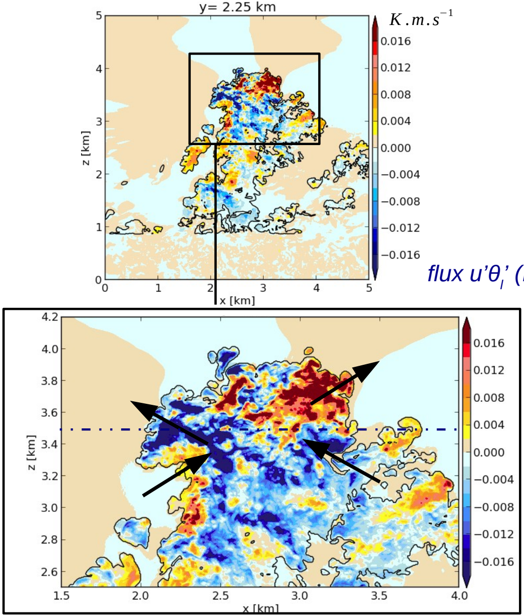
Surface fluxes:
LH 350 W/m²
SH 200 W/m²



Structure: toroidal circulation



streamlines



flux $u'\theta_l'$ ($K.m.s^{-1}$)

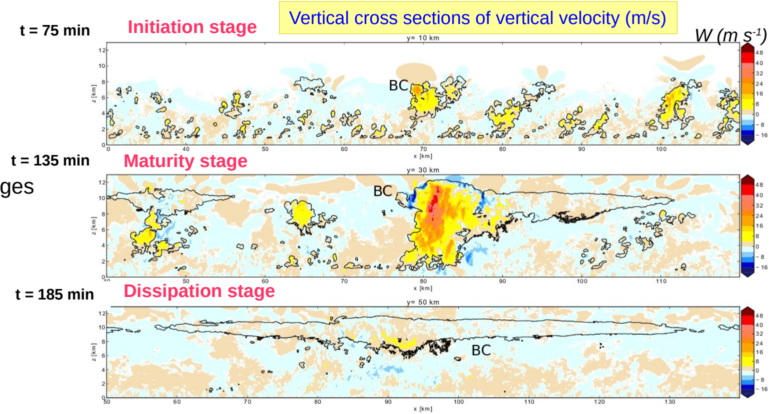
LES of deep convective clouds

- Generalization of previous results:

  Strauss, Ricard, Lac, Verrelle 2019 QJRMS

- New LES (50-m grid spacing):
  - on a larger domain: 80x80 km²
  - during 4 hours:

    Population of clouds at different stages



- Off-line evaluation for vertical and horizontal thermodynamical fluxes and dynamical fluxes of 3 schemes:

H-gradient formulation MOENG K-gradient formulation CBR K-gradient formulation SMAG

SMAG

Smagorinsky,1963

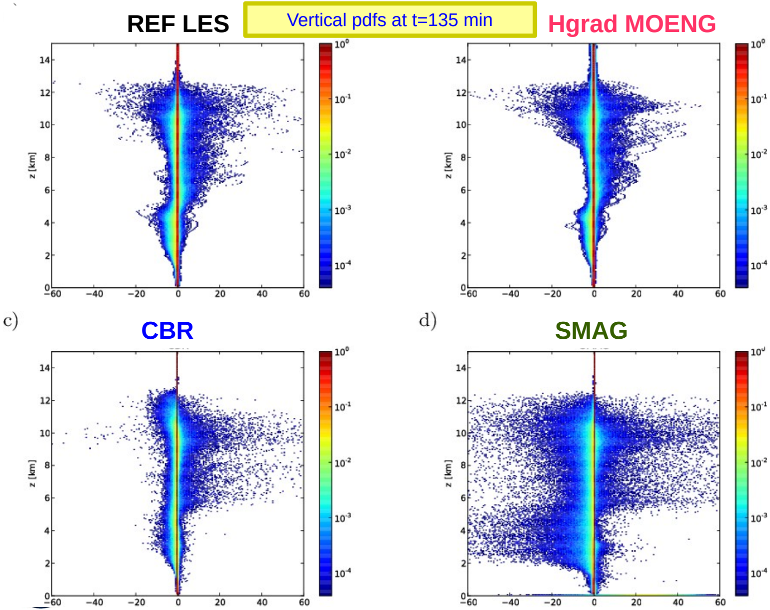
$$\overline{u'_i r'_{np}}^{\Delta x} = -\frac{(c_s L)^2}{Pr}\overline{D}\sqrt{max(0,1-\frac{Ri}{Pr})}\frac{\partial \overline{r_{np}}^{\Delta x}}{\partial x_i}$$

$$\overline{u'_i r'_{np}} = -K\frac{\partial \overline{r_{np}}}{\partial x_i}$$

Ri Richardson number
Pr Prandtl number
$\overline{D}$ deformation tensor

Evaluation of turbulence parameterization

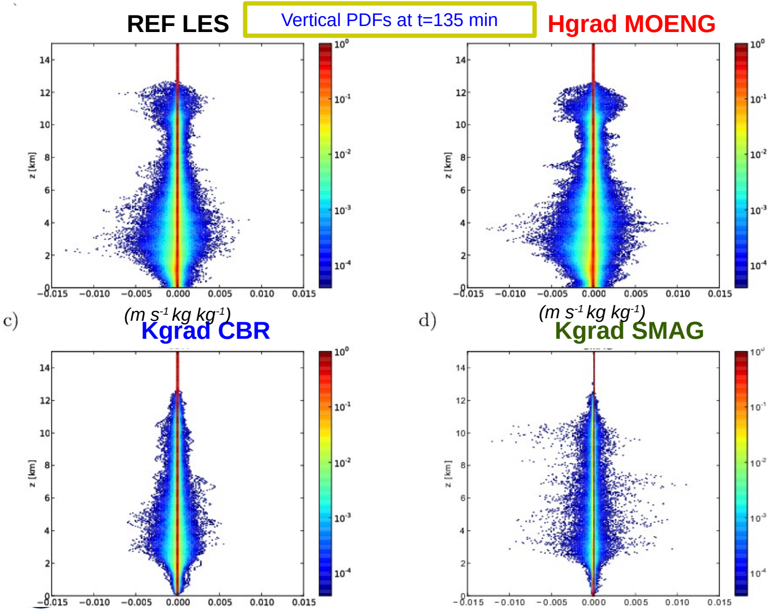
Vertical pdfs at t=135 min



Off-line evaluation $\overline{w'\theta'_l}$ *(m s^{-1} kg kg^{-1})*

Thermodynamical fluxes:
Better distribution with Hgrad

Evaluation of turbulence parameterization



Vertical PDFs at t=135 min

REF LES

Hgrad MOENG

Kgrad CBR

Kgrad SMAG

Off-line evaluation: $\overline{u'r'_{np}}$ (m s^{-1} kg kg^{-1})

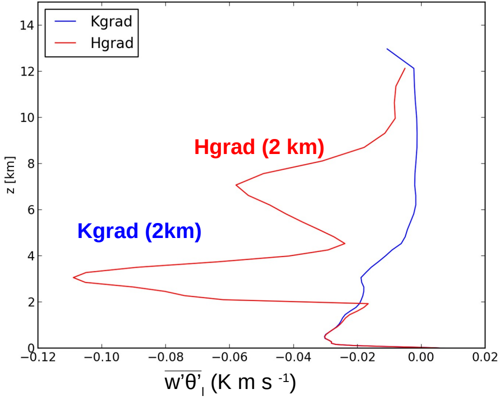
Δx = 1 km

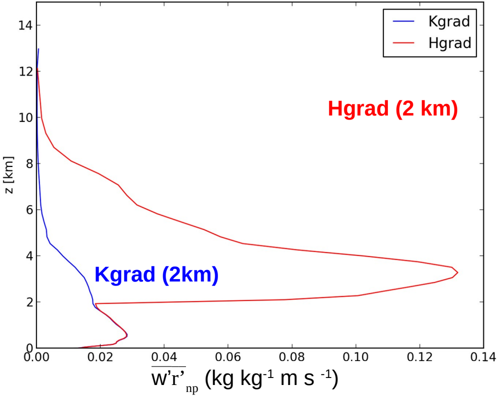
Thermodynamical fluxes:
Better distribution with **Hgrad**

Dynamical fluxes:
Slightly better with **Hgrad** but
better variances with **CBR**

Turbulent fluxes inside convective systems

Mean vertical profiles inside convective clouds between 21UTC 23 September and 10 UTC 24 September 2012





→more intense subgrid turbulent fluxes the **Hgrad run** compared to the **Kgrad run**