Study of the dynamics of convective rain cells using the Lokal model

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Work layout: goals

- The main goal of this work package has been to study the properties of convective cells performing high resolution runs with the non-hydrostatic limited area model Lokal;

- Intense storms in the Mediterranean often have a significant component of convective precipitation

- A deeper understanding of the properties and the dynamics of convective rain cells is warranted both from physical and operational (LMK project) points of view. The idea is to use the Lokal model as a numerical framework for studying the dynamics of convective rain cells in simplified model configurations

Work layout: method (2)

• High resolution simulations of deep moist convective structures over a flat surface at the interface between the meso-γ and the micro-α scales have been performed;

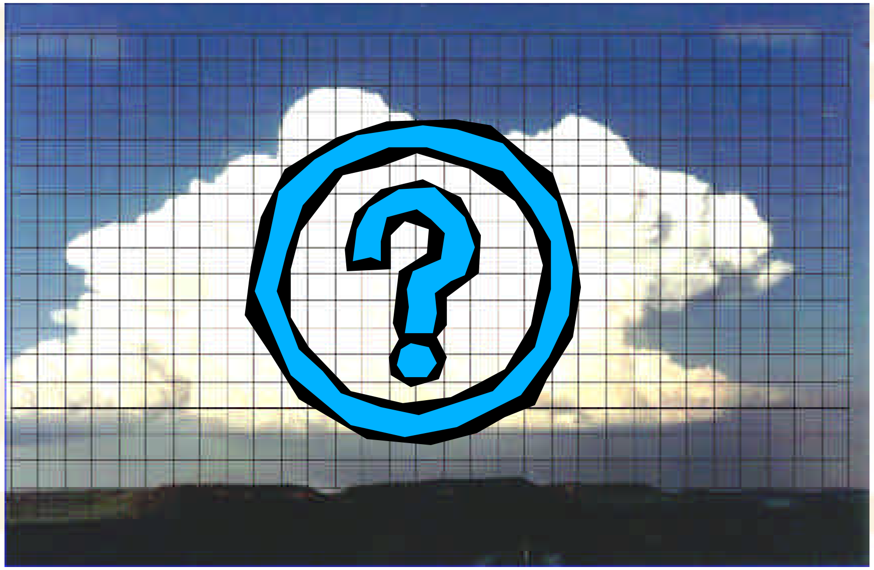
• In this way, hopefully, deep moist convective processes and the feedback mechanisms to larger scales of motion can be resolved explicitly and some of the critical constraints of parameterisation schemes can be relaxed;

• Potential benefits of high resolution deep convection simulation can arise from: more detailed representation of cloud-microphysics, transport of convective cells with the wind field (impact of shear) and gust front dynamics (long-lasting cells, super- and multi-cells development)

Deep convection modeling

Often simulated convective structures are found to be very sensitive variations in model physical and computational parameters.

Grid spacing, numerical diffusion, microphysics options and the coefficient of surface friction are found to alter, in some cases seriously, the spatio-temporal properties of deep convective structures

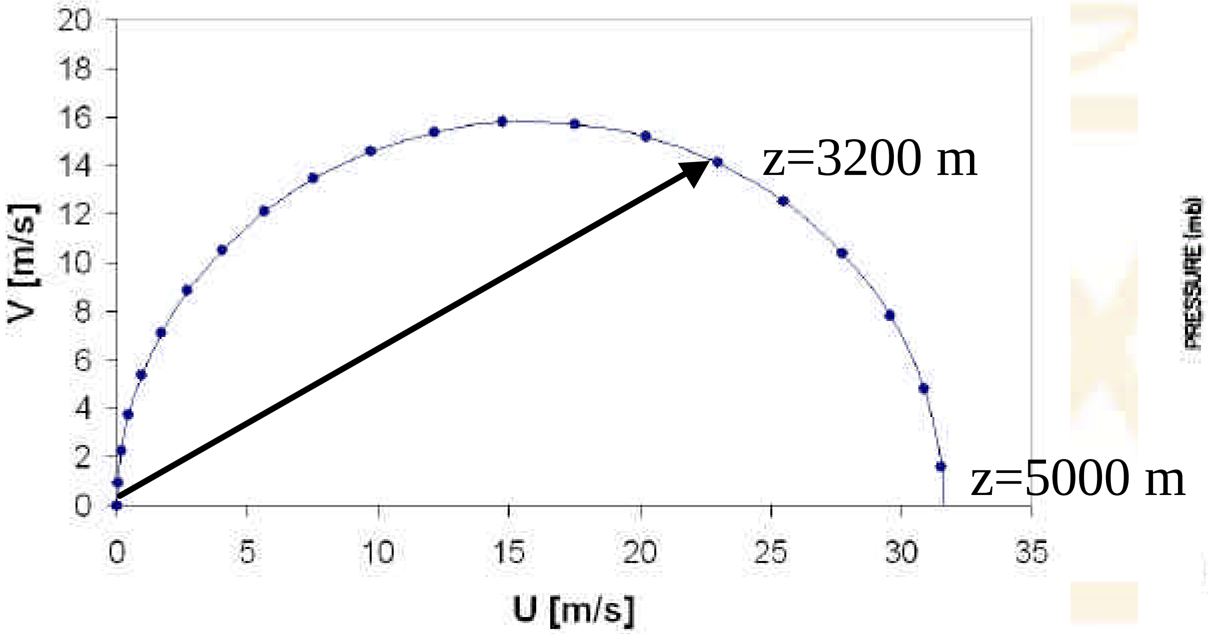


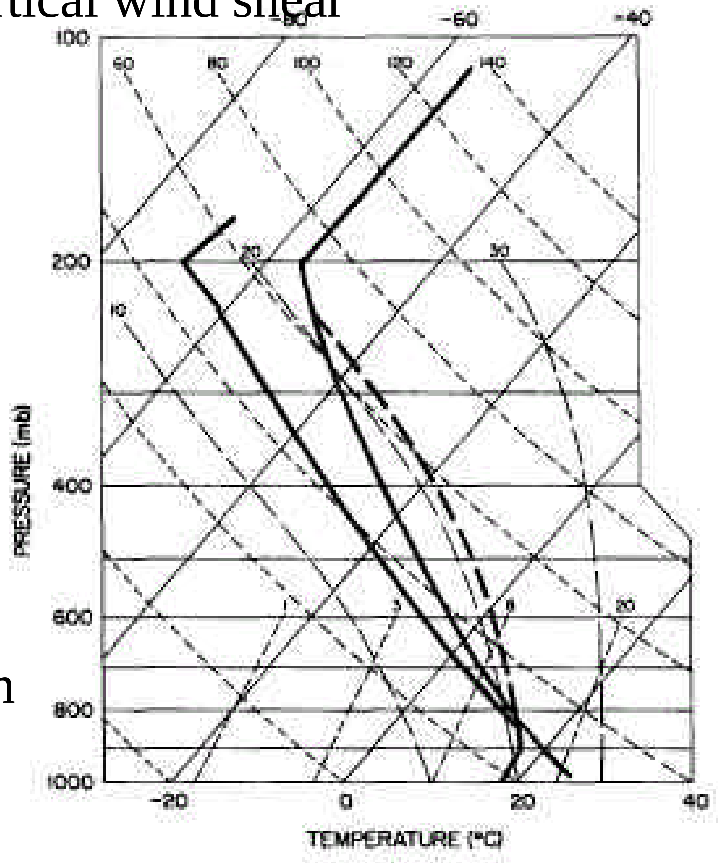
Experiment 1: deep convection + veering vertical wind shear

Domain 300x300x18 km, no orography , Davies relaxation boundary conditions, Kessler microphysics, no atmospheric radiation, Leapfrog HE-VI time integration scheme, 4th order linear horizontal diffusion, 2.5 scheme with prognostic treatment of turbulent kinetic energy, Rayleigh damping layer in upper layers.

Initial conditions (Weisman and Klemp, 1982,1984)

Warm bubble + veering vertical wind shear





Experiment 1: deep convection + veering vertical wind shear

4^{th} order horizontal diffusion coefficient

$\Delta x = \Delta y$ = 1km, Δt= 1s

$$M_y^{CM} = K_4^h \nabla^2 \left(\nabla^2 y \right)$$

$$K_{4,\max}^h = \frac{(\Delta x)^4}{128 \Delta t}$$

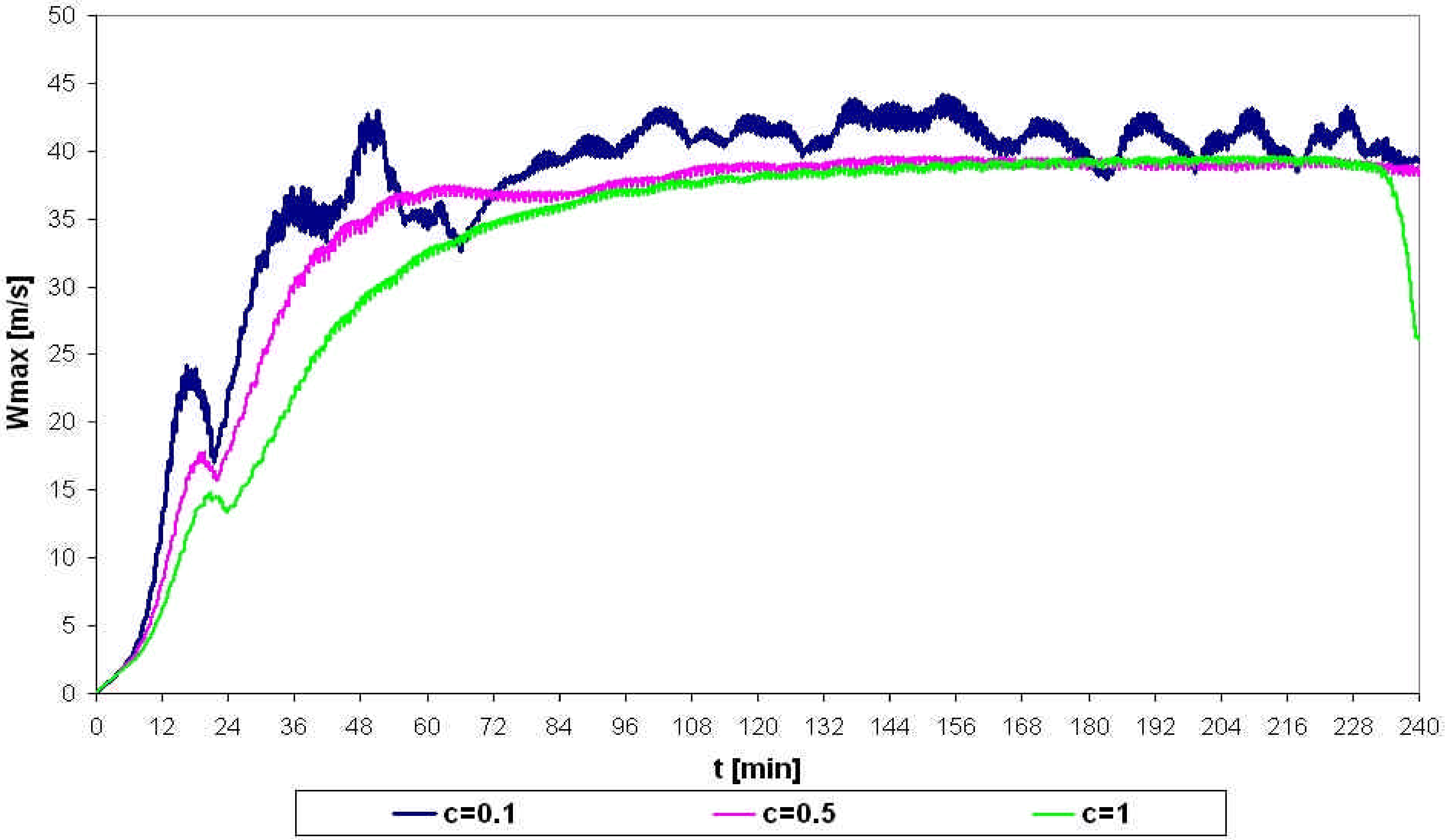
$$K_4^h = c\, K_{4,\max}^h$$

Run	c
1	0.1
2	0.5
3	1

Experiment 1: deep convection + veering vertical wind shear

4th order horizontal diffusion coefficient

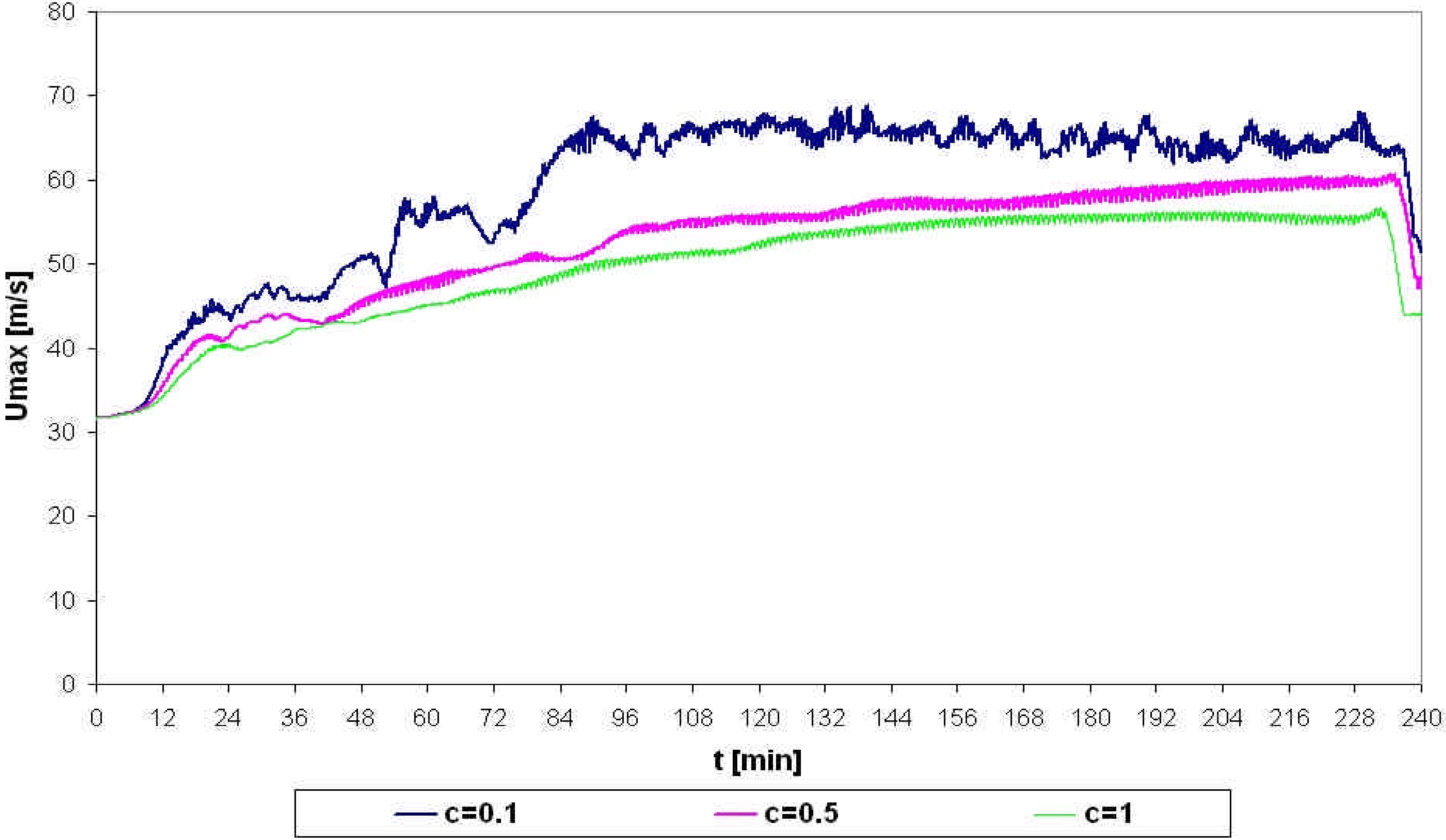
$\Delta x = \Delta y = 1km, \Delta t = 1s$



Experiment 1: deep convection + veering vertical wind shear

4th order horizontal diffusion coefficient

$\Delta x = \Delta y = 1km, \Delta t = 1s$

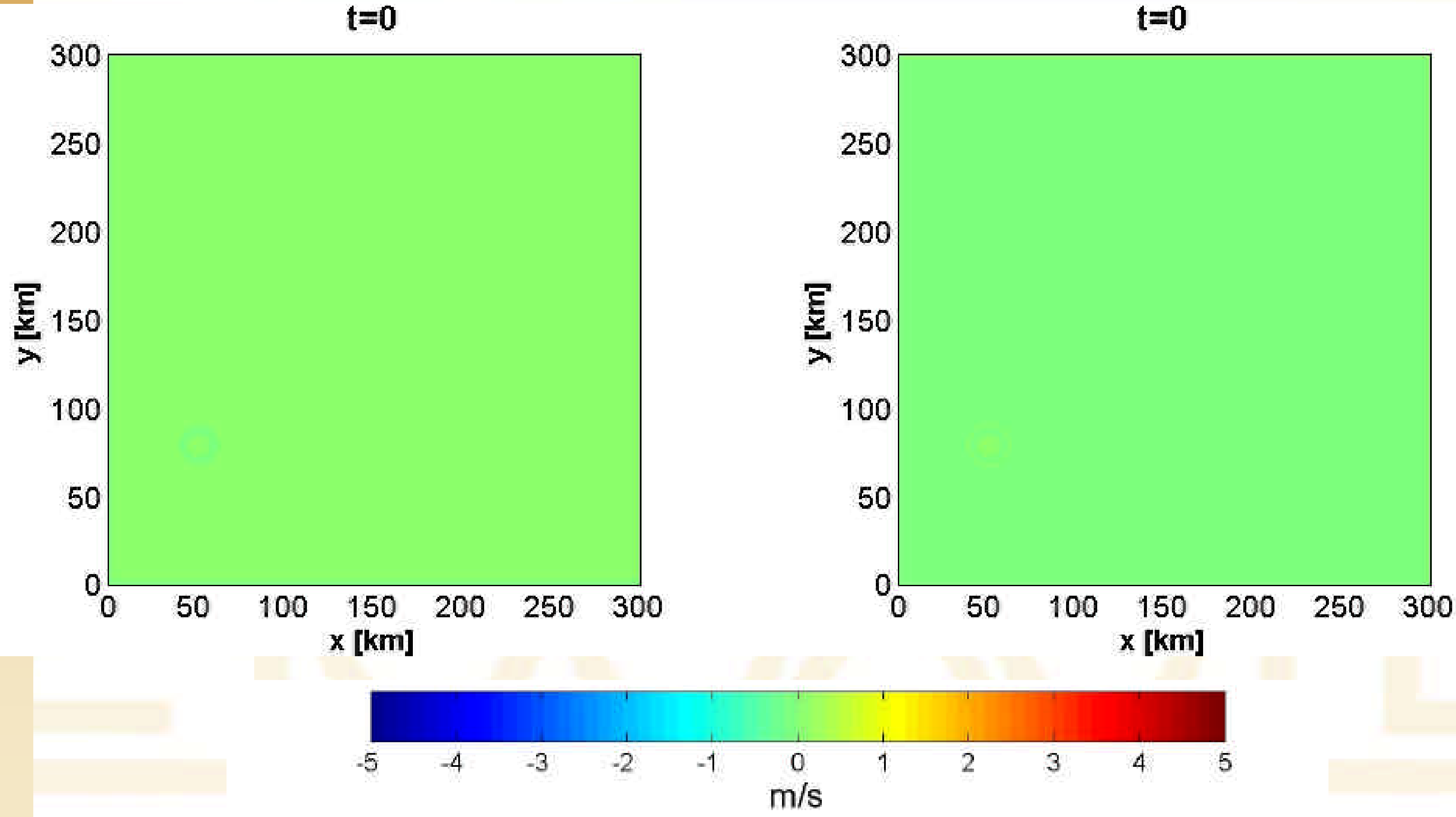


Experiment 1: deep convection + veering vertical wind shear

$\Delta x = \Delta y = 1km, \Delta t = 1s$

Horizontal cross section w, z~1000 m

c=0.1 c=0.5

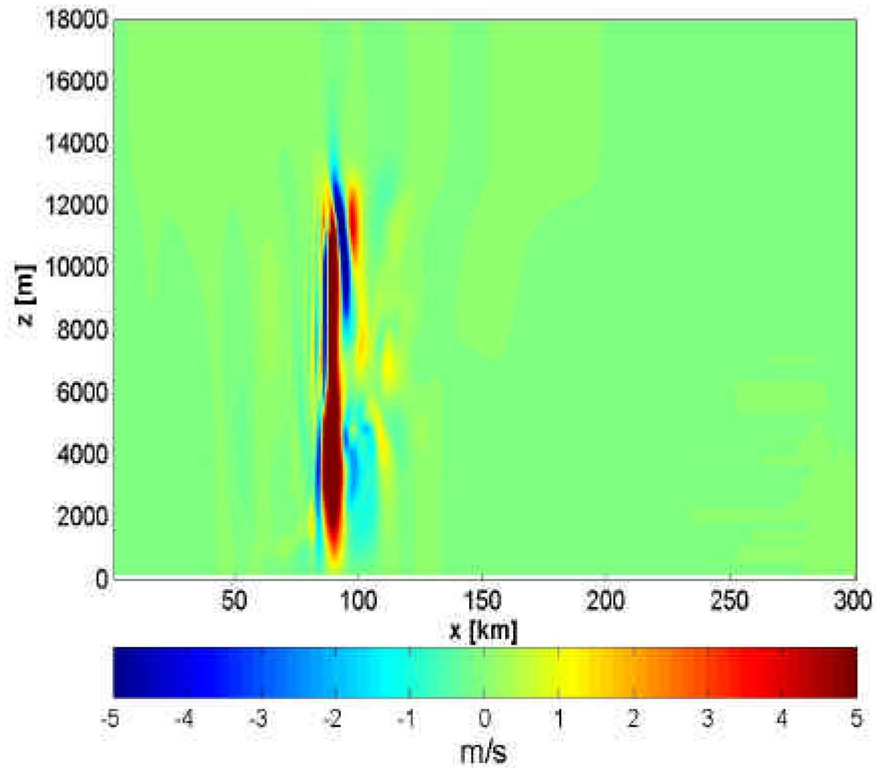


Experiment 1: deep convection + veering vertical wind shear

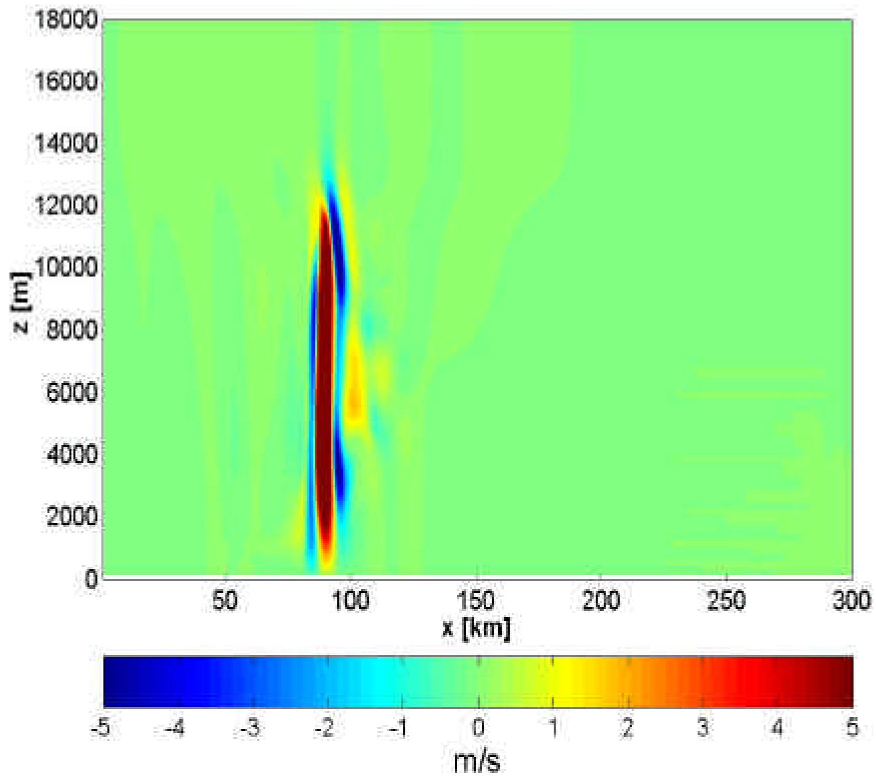
$\Delta x = \Delta y = 1km$, $\Delta t = 1s$

t= 42 min, vertical cross section w, y=100 km

c=0.1



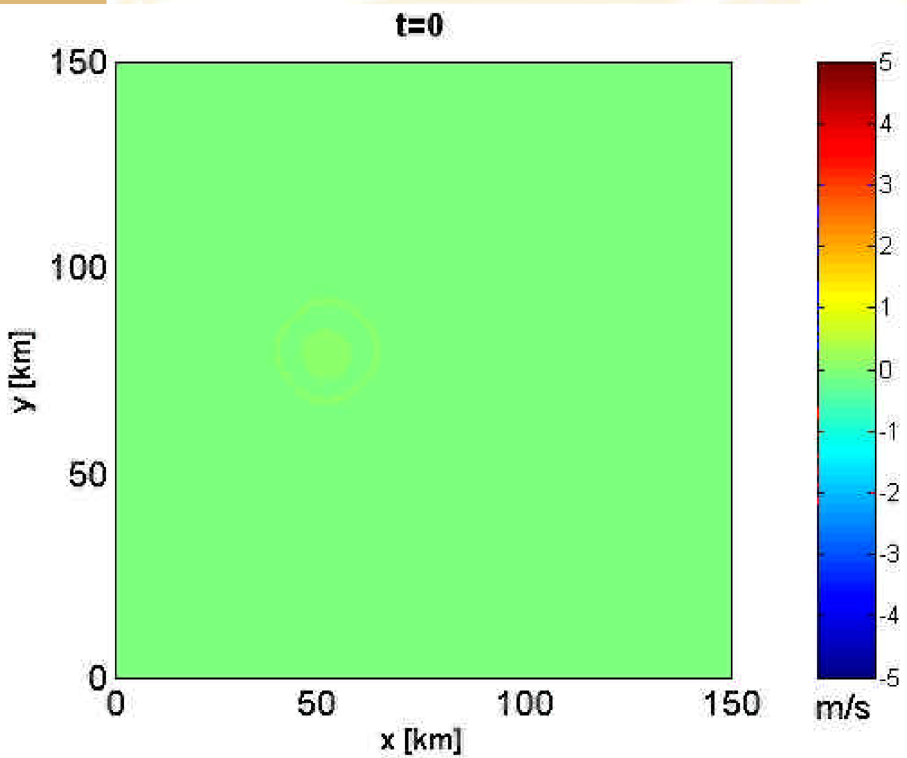
c=0.5



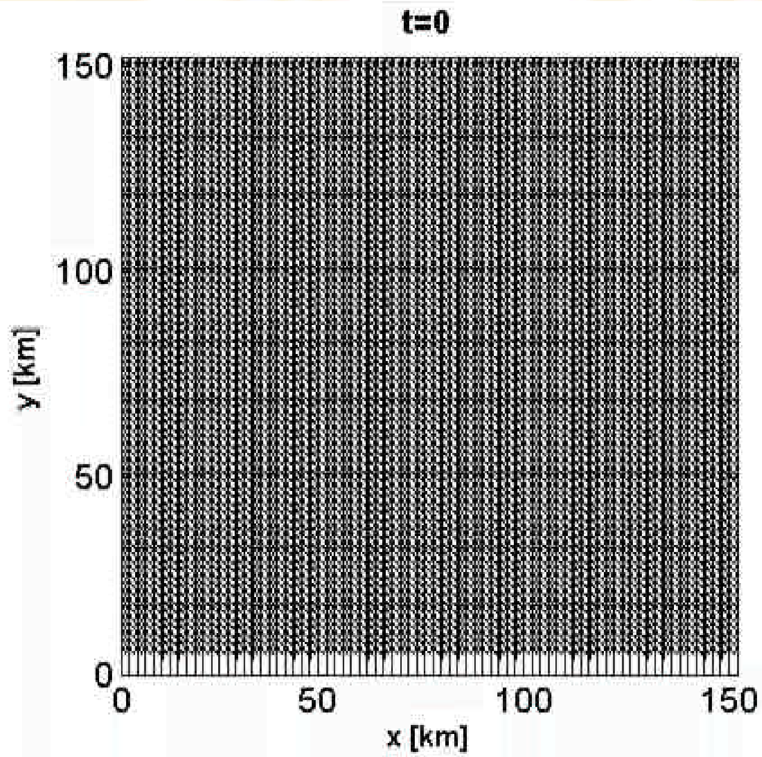
Experiment 1: deep convection + veering vertical wind shear

$$\text{Generation of secondary cells is due to} \begin{cases} \text{Cold pool} - \text{shear interaction?} \\ \text{Propagation of acoustic / gravity waves?} \end{cases}$$

Horizontal cross section w, z~1000 m



Horizontal cross section (u,v) , z~100 m

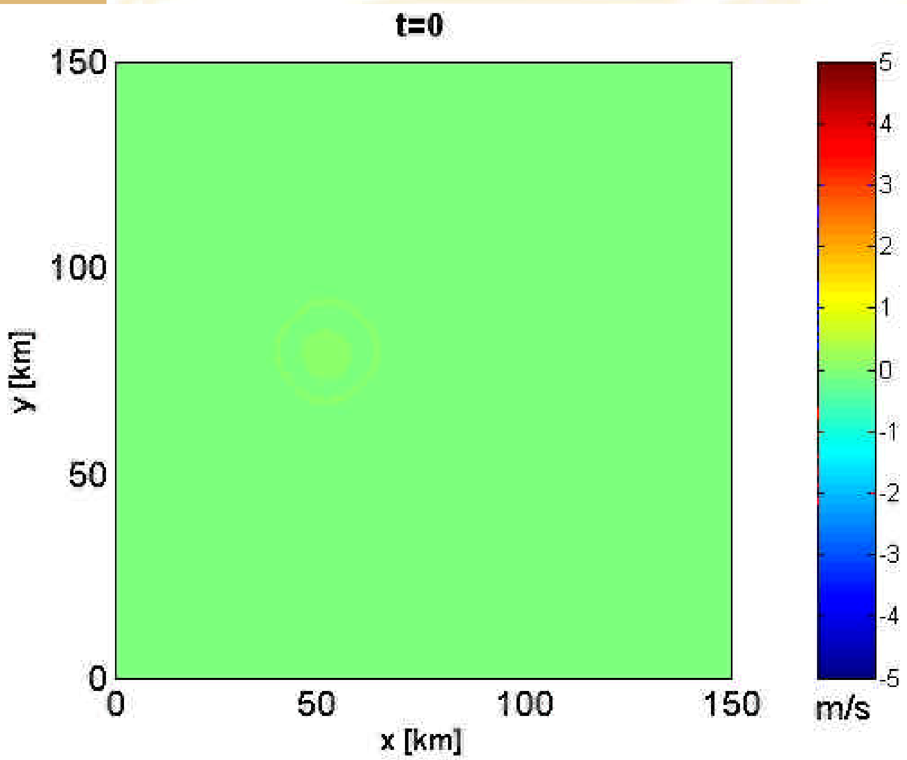


Experiment 1: deep convection + veering vertical wind shear

$$\textit{Generation of secondary cells is due to} \begin{cases} \textit{Cold pool} - \textit{shear interaction}? \\ \textit{Propagation of acoustic / gravity waves}? \end{cases}$$

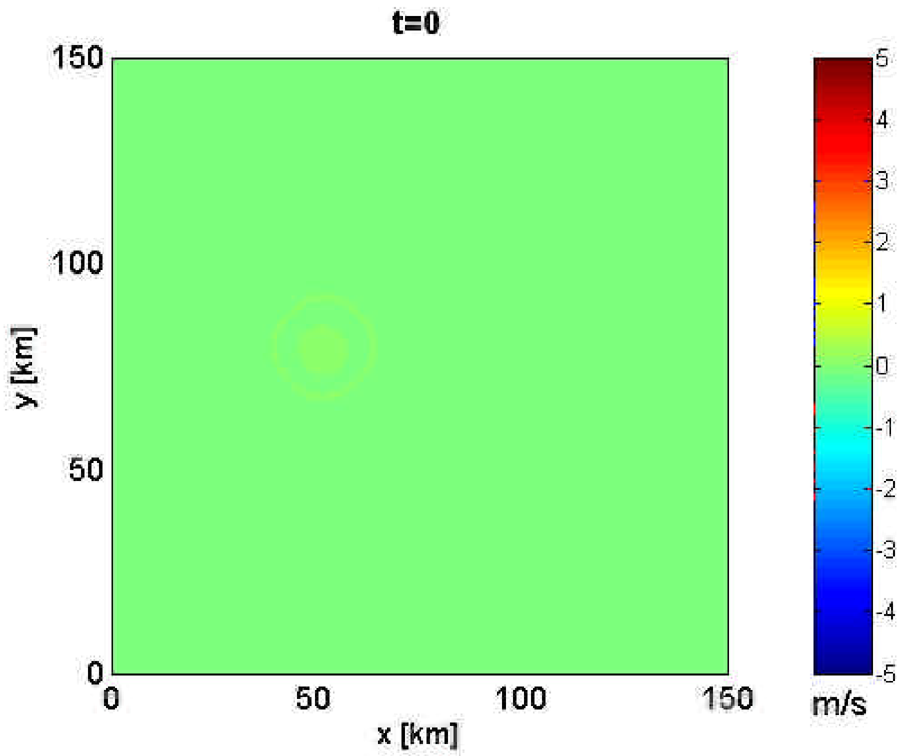
Horizontal cross section w, z~1000 m

Precipitating run



Horizontal cross section w, z~1000 m

Nonprecipitating run



Experiment 1: deep convection + veering vertical wind shear

Horizontal grid spacing effect

Run 2 is the"control run" and by assuming a reference value of K_4^h, it is evaluated the effect of horizontal grid spacing on model behaviour.

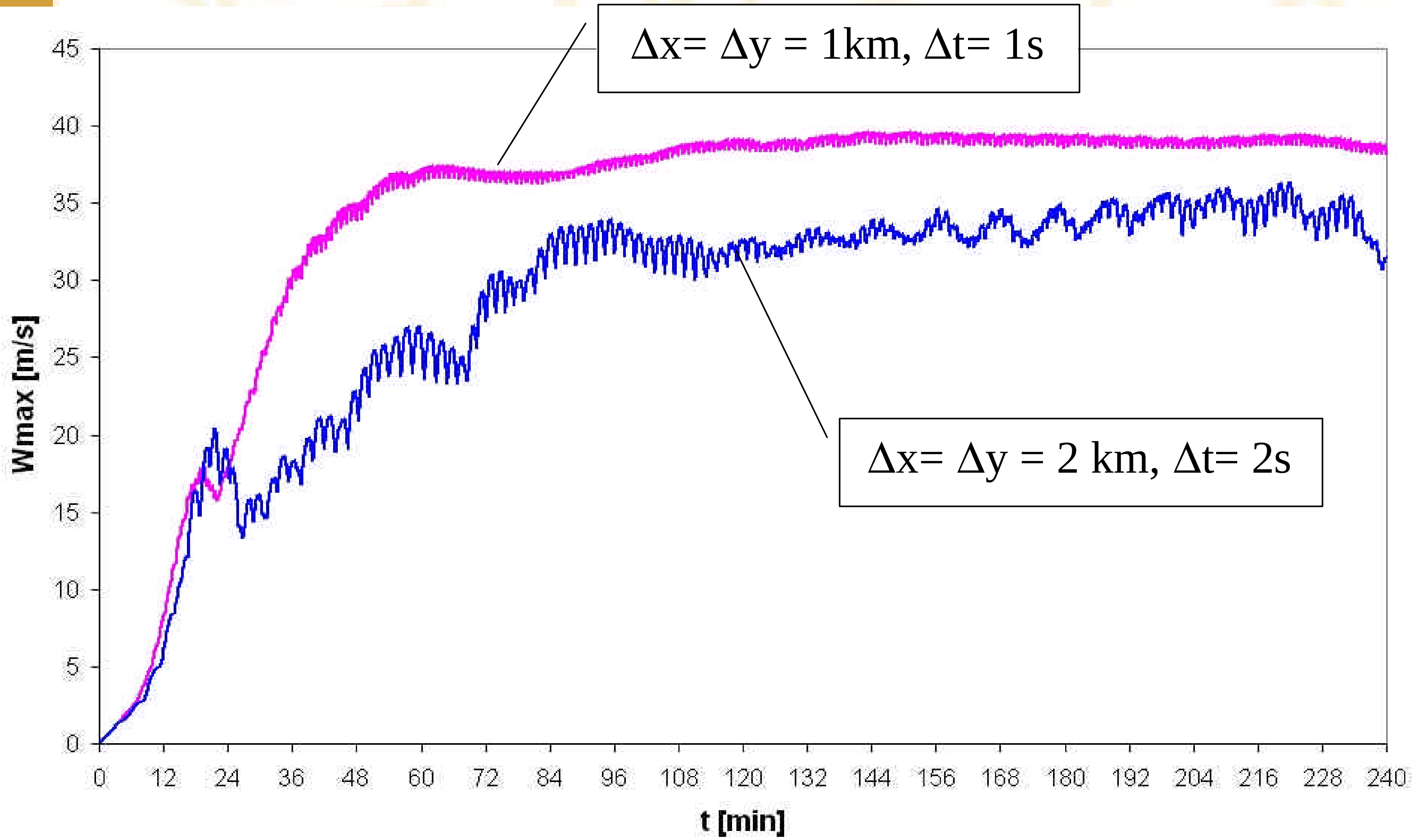
$\Delta x = \Delta y = 2$ km, $\Delta t = 2$ s

The remaining computational details are kept the same

$$\left(K_4^h\right)_{\Delta x=1km} = \left(K_4^h\right)_{\Delta x=2km}$$

Experiment 1: deep convection + veering vertical wind shear

Horizontal grid spacing effect



Experiment 1: deep convection + veering vertical wind shear

$\Delta x = \Delta y = 1$ km

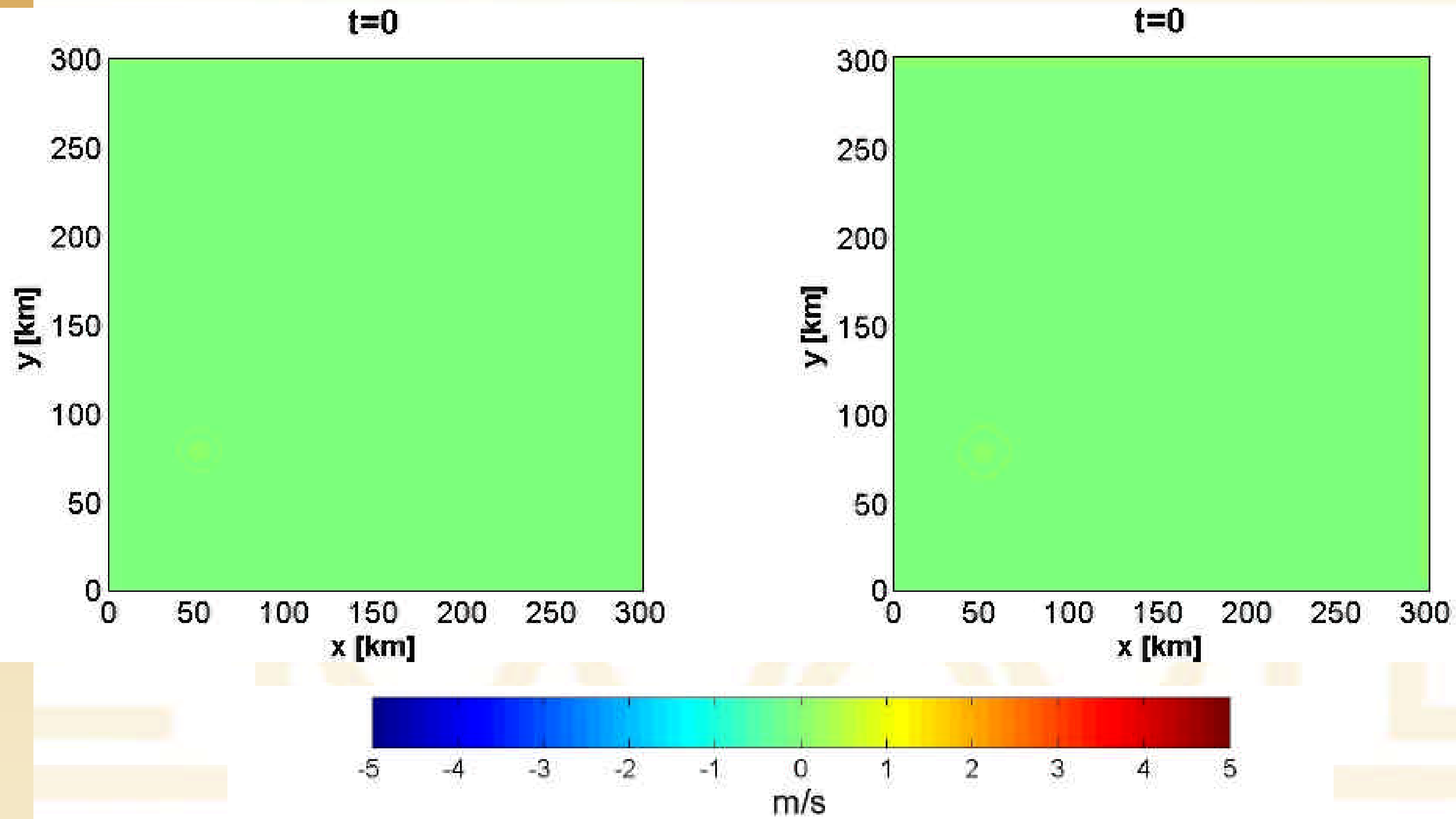
$\Delta t = 1$s

Horizontal cross section w, z~1000 m

$\Delta x = \Delta y = 2$ km

$\Delta t = 2$ s

Horizontal cross section w, z~1000 m



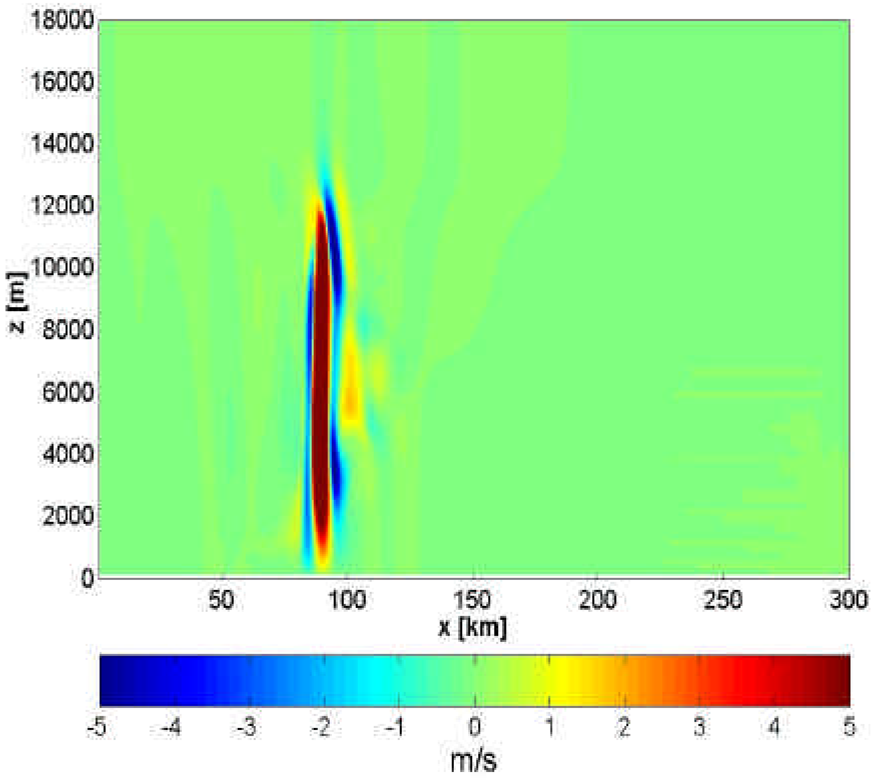
Experiment 1: deep convection + veering vertical wind shear

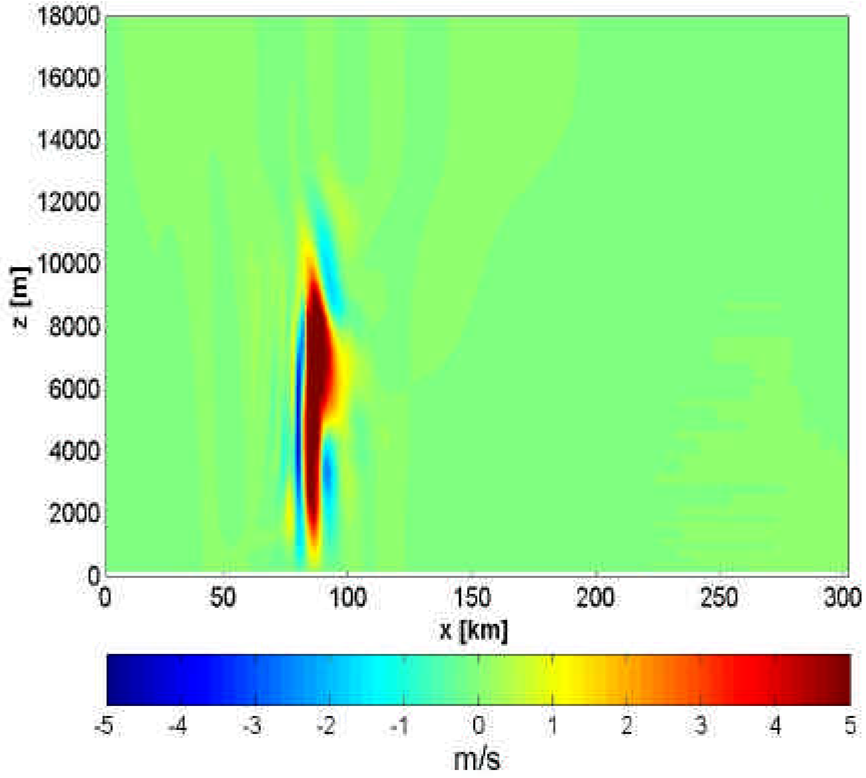
t= 42 min, vertical cross section w, y=100 km

$\Delta x = \Delta y = 1\text{km}$ $\qquad$ $\Delta x = \Delta y = 2\text{ km}$

$\Delta t = 1\text{s}$ $\qquad$ $\Delta t = 2\text{ s}$

$$\left(K_4^h\right)_{\Delta x=1km} = \left(K_4^h\right)_{\Delta x=2km}$$

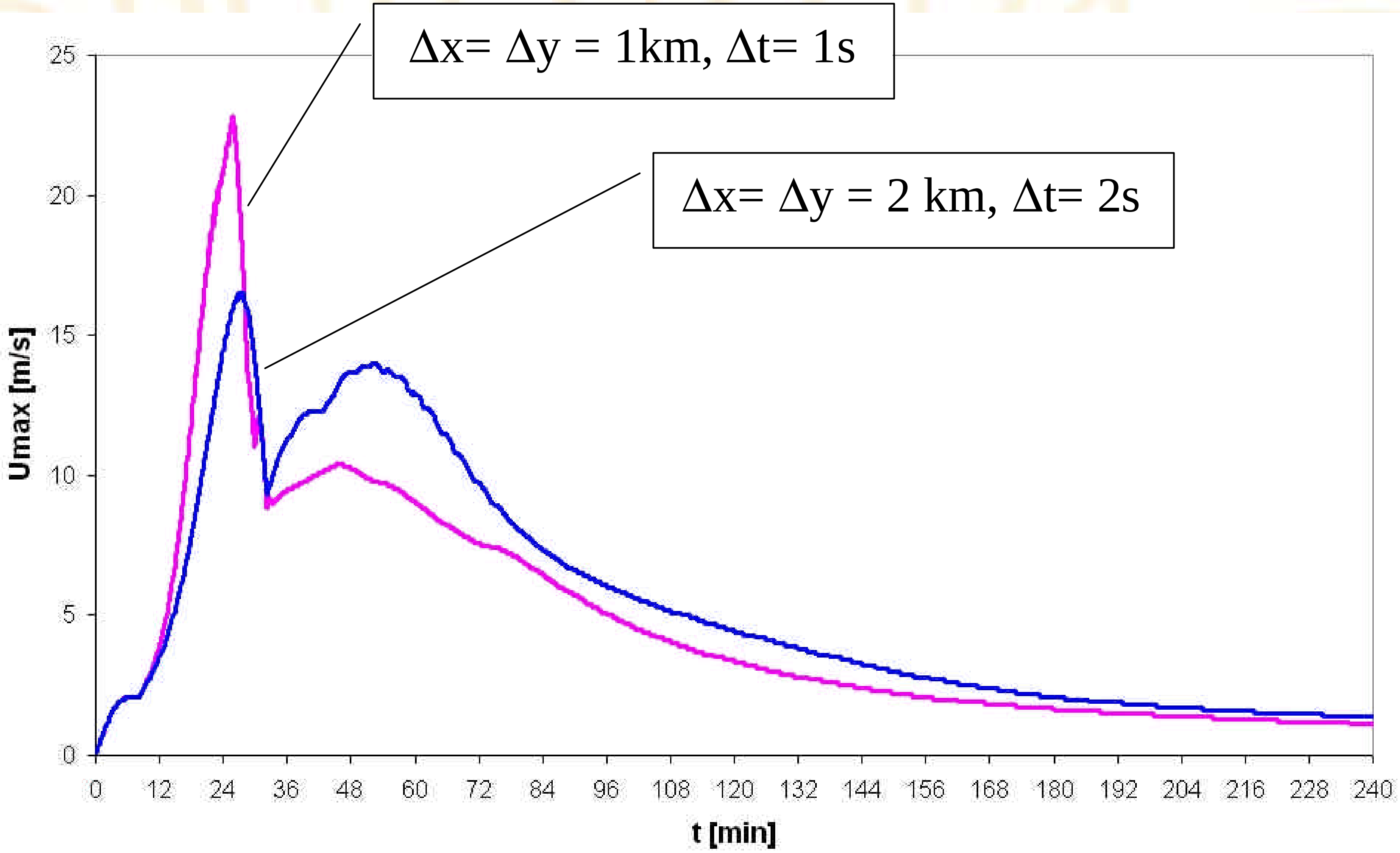




Experiment 2: deep convection without vertical wind shear

Horizontal grid spacing effect c=0.5

$$\left(K_4^h\right)_{\Delta x=1\,km} = \left(K_4^h\right)_{\Delta x=2\,km}$$

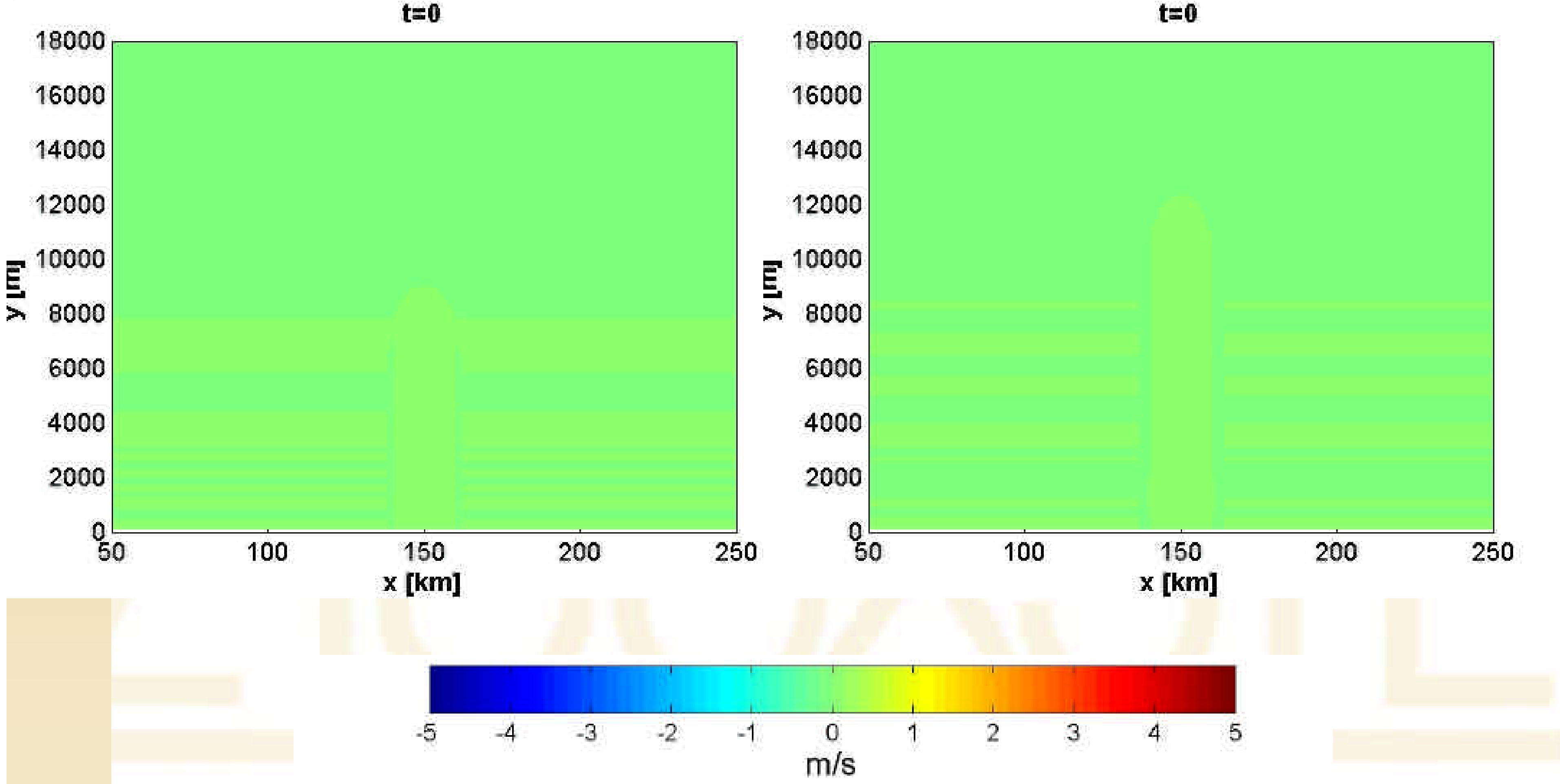


Experiment 2: deep convection without vertical wind shear

Horizontal grid spacing effect

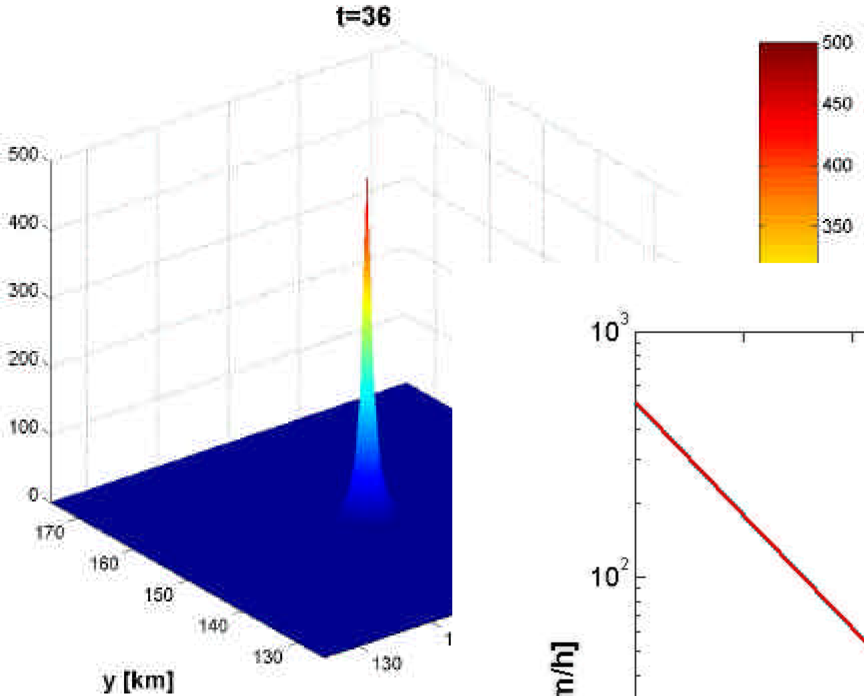
c=0.5

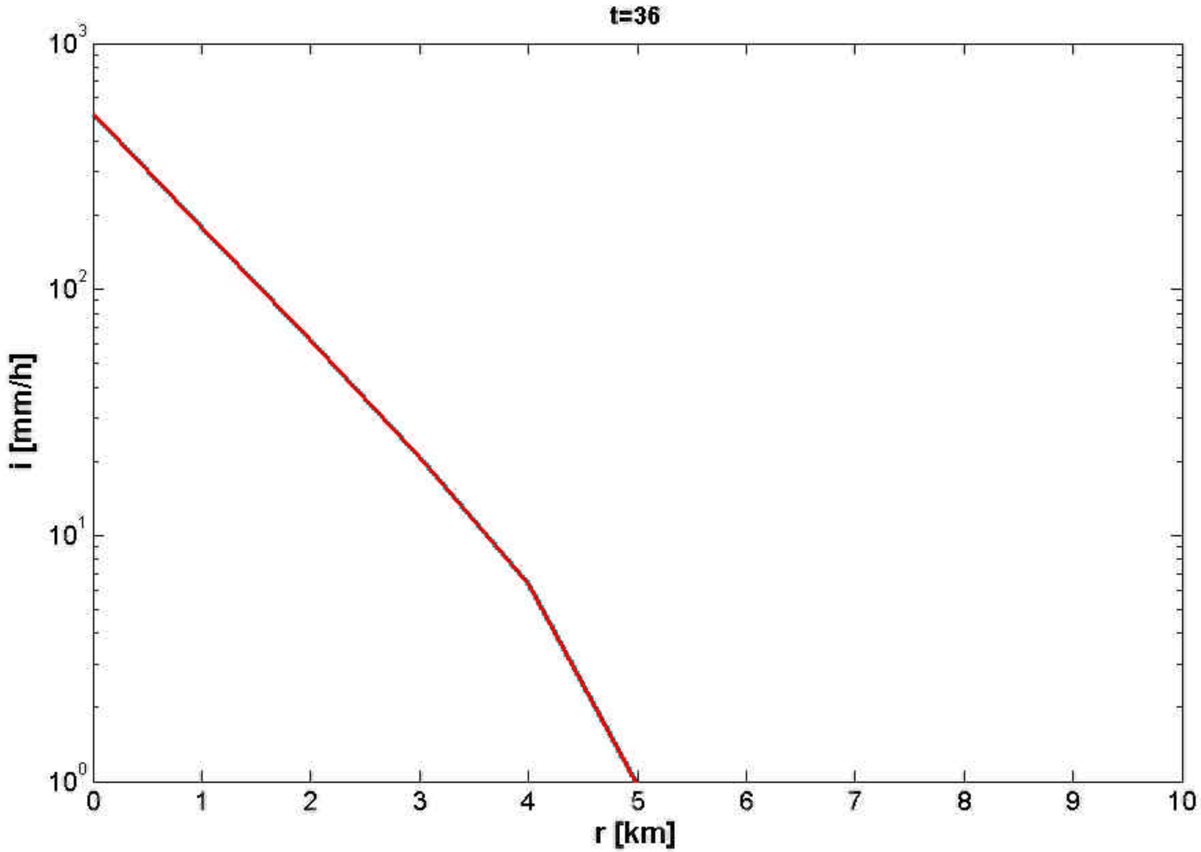
$$\left(K_4^h\right)_{\Delta x = 1\,km} = \left(K_4^h\right)_{\Delta x = 2\,km}$$



Experiment 2: deep convection without vertical wind shear

von Hardenberg et al. (2003) have recently shown that convective rain cells have an exponential profile





Conclusions

- The dynamics of convective rain cells simulated by means of non-hydrostatic high resolution model (Lokal model) is found to be quite dependent on numerical and physical parameters such as numerical diffusion and horizontal grid spacing (see also Adlerman et al., 2002);

The work is in progress:

- The spatio-temporal properties of convective rain cells generated by integrating the Lokal model will be compared with those typical of intense convective cells at mid-latitudes
- Evaluation of the role of other parameters (microphysical scheme, surface drag coefficient) also at lower horizontal resolution (500-250 m);

- Implications of these results in our understanding of storm dynamics as well as in the context of LAM numerical weather prediction should be considered;

- Some of these results will be used to develop physically-based rainfall downscaling models

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