New dynamical core of COSMO –"COSMO-EULAG operationalization (CELO)" Priority Project

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Outline

- Integration and consolidation of the EULAG compressible DC with the COSMO framework

  - physical aspects: boundary conditions, dynamics physics coupling

  - technical aspects: compilers, test suite

- Technical testing of the coupled model by idealized dry test cases

Cold density current (Straka et al., 1993)
Bubble convection test (Robert, 1993)

COSMO-EULAG code optimization

- COSMO-EULAG code optimization focused on the efficiency of the MPDATA advection procedures.

- The work included preparation of the custom MPDATA (and velocity predictor) versions for open boundary conditions, focused on the NWP performance.

- Unnecessary memory stores were removed and the loops were merged, whenever possible.

Numerical performace

- We run 24 hour forecast for 3.06.2013
- Time interval between data dumps 3 hours
- 20x40=800 cores Intel(R) Xeon(R) CPU E5-2690 v2 @ 3.00GHz
- Horizontal diffusion not included
- Accuracy of the pressure solver set as 0.0005 times maximum velocity divergence

	Compressible [s]	Anelaestic [s]
MPDATA dry advection	178	89
MPDATA moist advection	154	146
GCR iterative solver	252	226
Time for the total model run:	**1312**	**1183**

The difference in total time between COSMO-RK and CE-compressible is of order **10%**

Ongoing work

- Pressure diagnosis is very sensitive to the setting of the coupling with moist physics. Therefore the current effort is aimed at the optimization of the coupling.
- As a test suit we use the explicit compressible solver which is built into the EULAG

Consolidation of the compressible dynamical core

Extensive diagnostics and debugging included:

- Preparation of the bit-reproducible version of the dynamical core with results independent of the processor distribution

- Testing of the dynamical core on Cray Fortran, PGI, Intel and GNU compilers with full diagnostic options

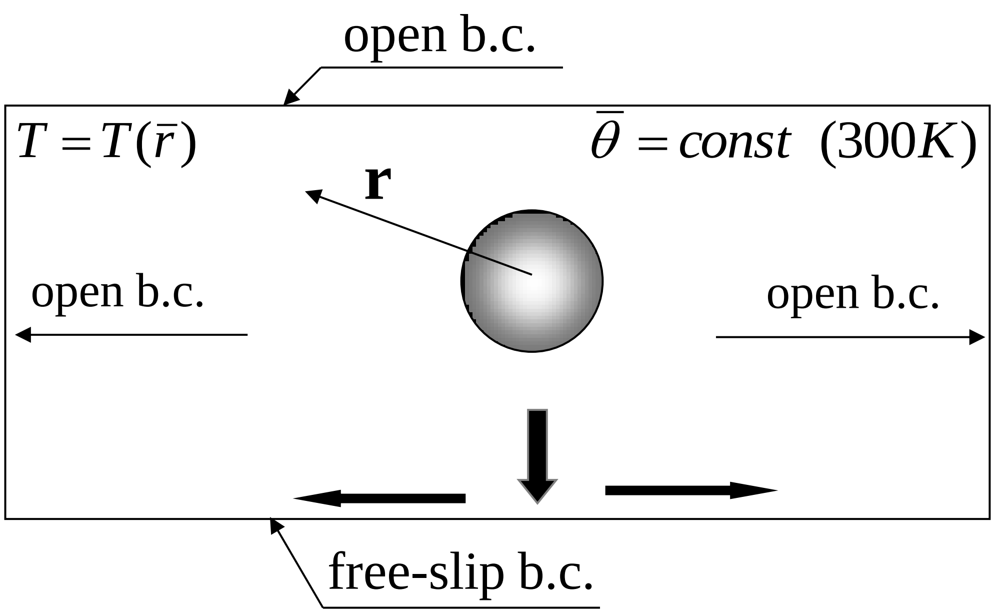
- COSMO-EULAG now has independent Parallel-Netcdf IO layer, allowing for on-demand disk store of 3D variables, 2D slices and 1D profiles

Two dimensional time dependent simulation of cold blob descending to the ground

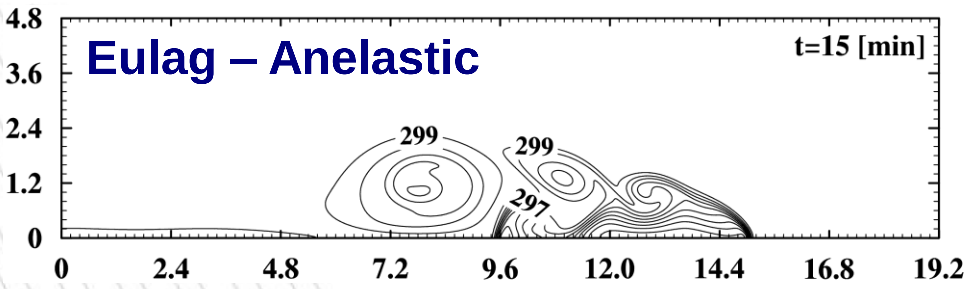
Straka, J. M., Wilhelmson, Robert B., Wicker, Louis J., Anderson, John R., Droegemeier, Kelvin K., Numerical solutions of a non-linear density current: A benchmark solution and comparison *International Journal for Numerical Methods in Fluids*, (**17**), 1993

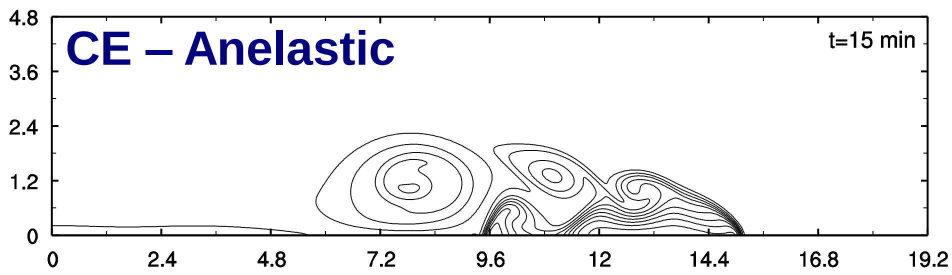
Experiment configuration:

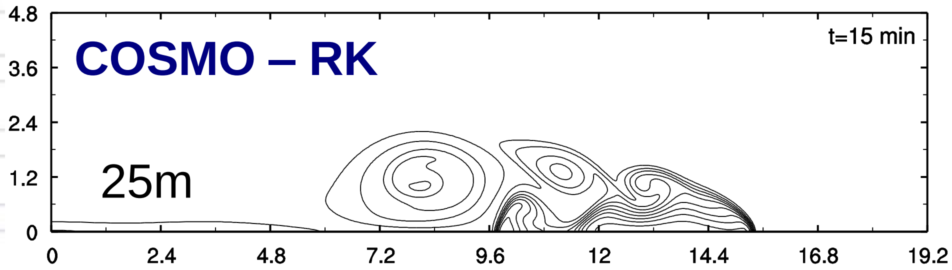
- isentropic atmosphere, θ(z)=const (300K)
- open lateral boundaries
- free-slip bottom b.c.
- **constant subgrid mixing, K=75m^2/s**
- domain size 51.2km x 6.4km
- bubble min. temperature -15K
- bubble size 8km × 4km
- no initial flow
- integration time 15 min
- isotropic computational mesh

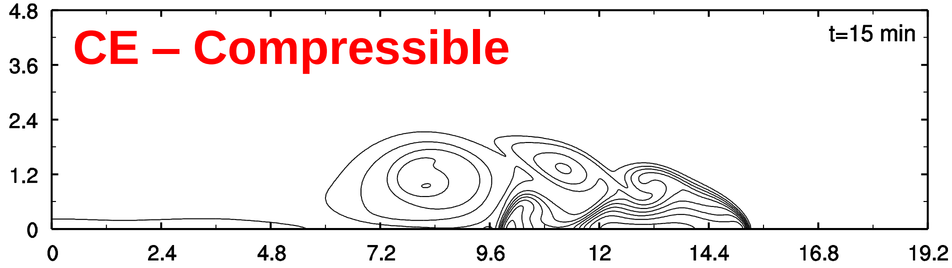


Distribution of potential temperature after 15 minutes
Solutions from differnt models

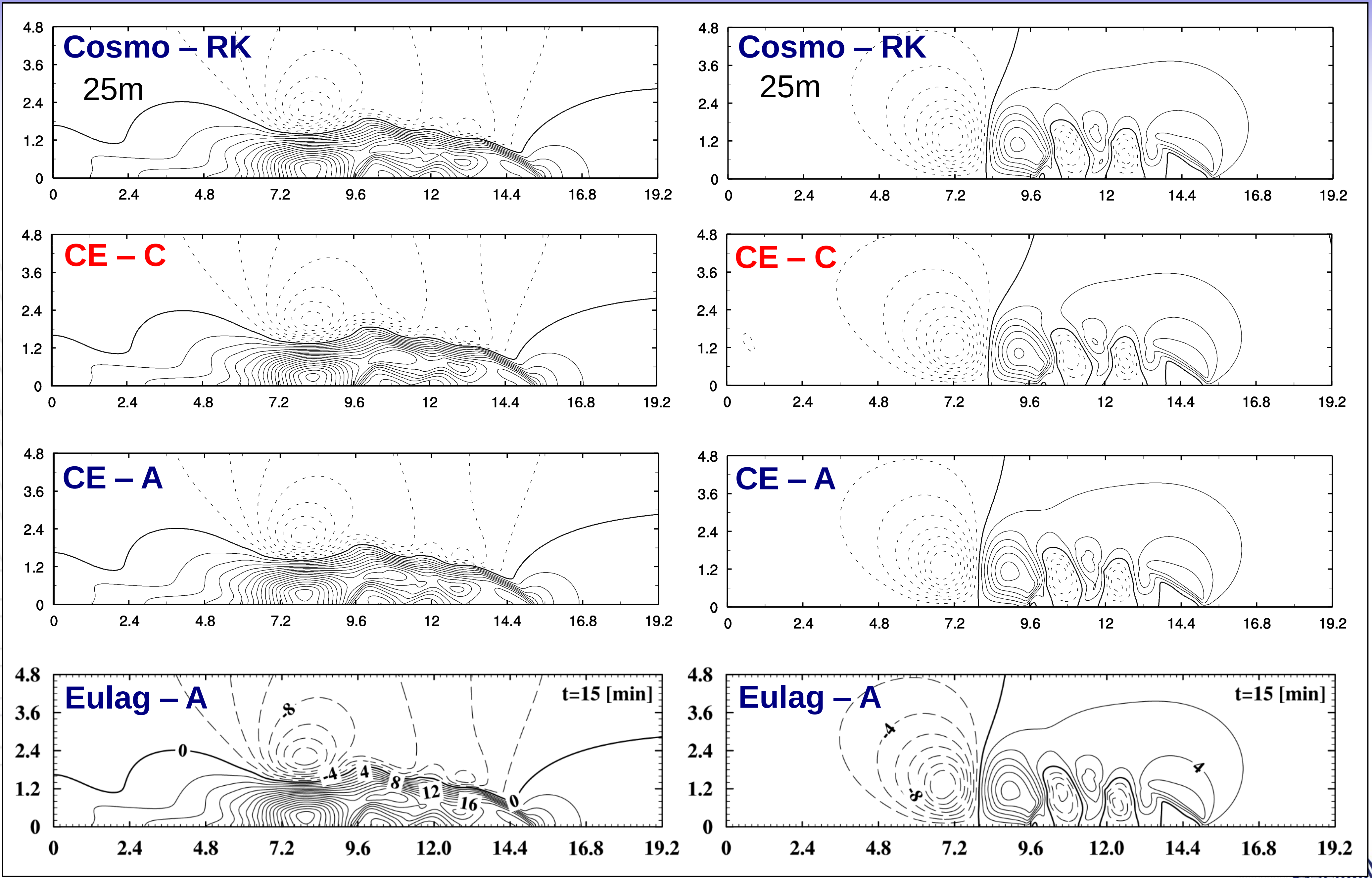








Comparison of horizontal and vertical velocities obtained using different models

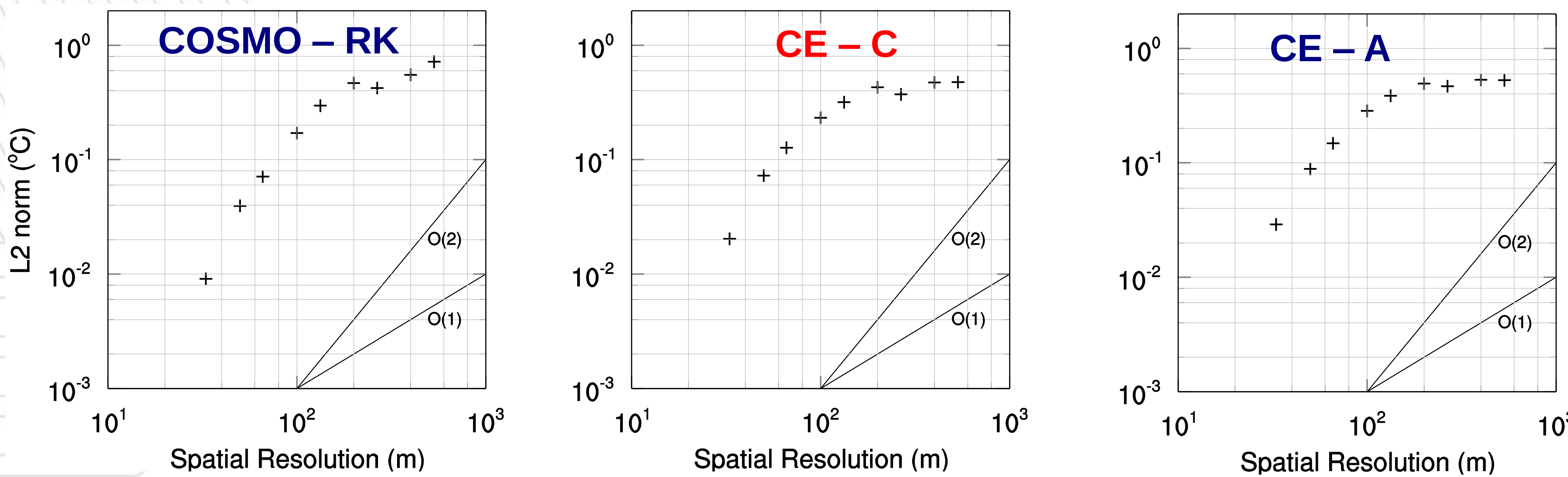


Self convergence of the solutions: L_2 norms of spatial truncation errors

For each dy-core of COSMO an enhancement of self-convergence for $\Delta x < 133$ m was observed. Tests were performed for each core separately.

- ΔT = 0.375 s
- Δx_{ref} = 25 m
- Δx = {33, 50, 66, 100, 133, 200, 266, 400, 533} m

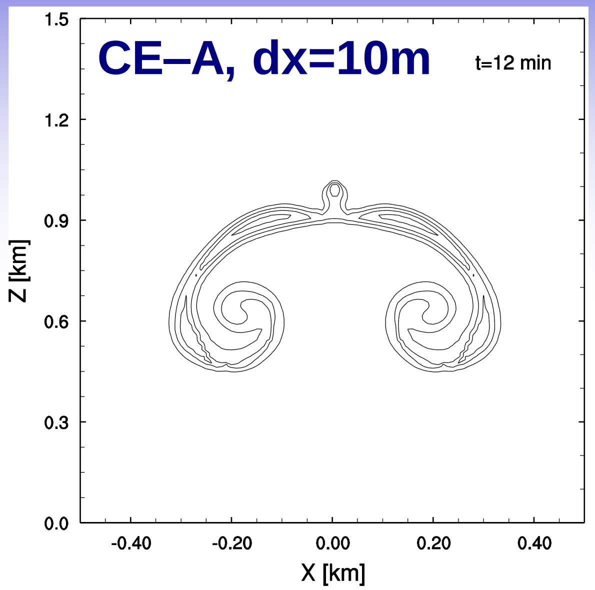
- L_2 norms calculated for potential temperature perturbation (Θ') are shown below

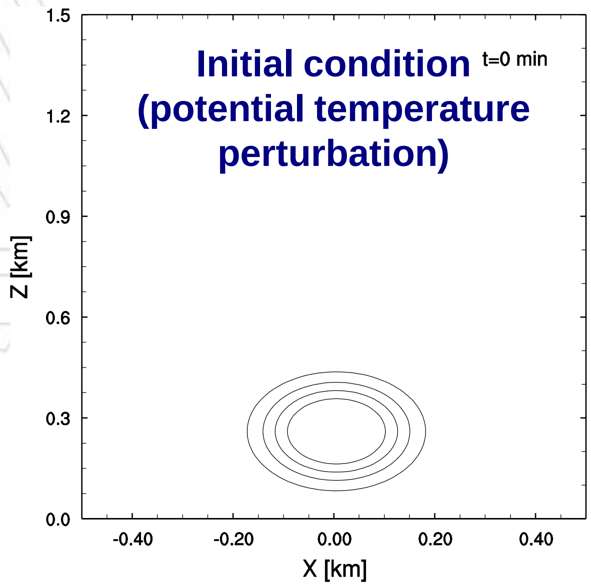


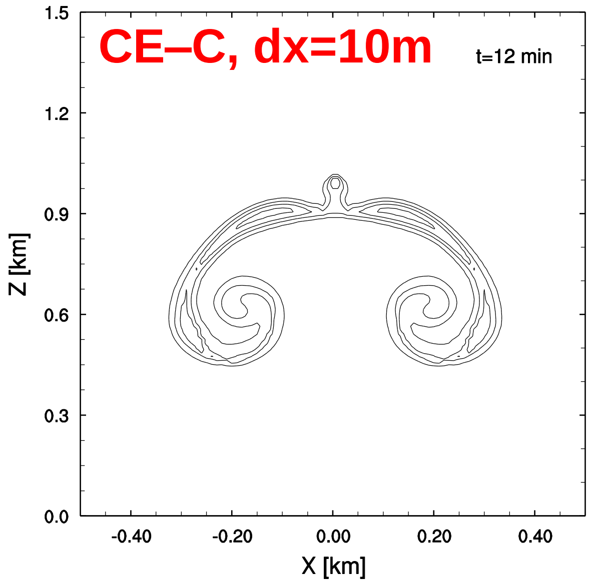
Bubble convection test (Robert, 1993)

Experiment no 1 :

- Isentropic atmosphere, θ(z)=const (300K)
- **Turbulence switched off**
- L_x=1 km, L_z=1.5 km
- dx = dz
- (dx, dt) = (10m, 2s) or (5m, 1s)
- ΔT_{warm}=0.5 K
- r_{warm}=250 m



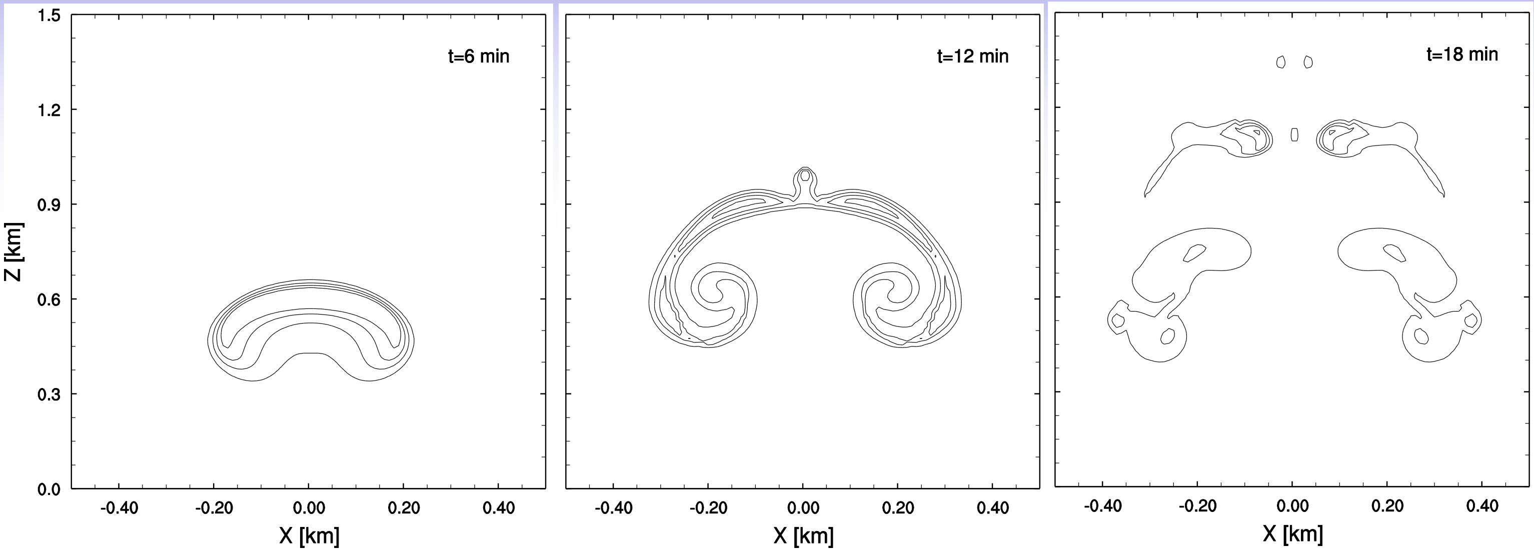




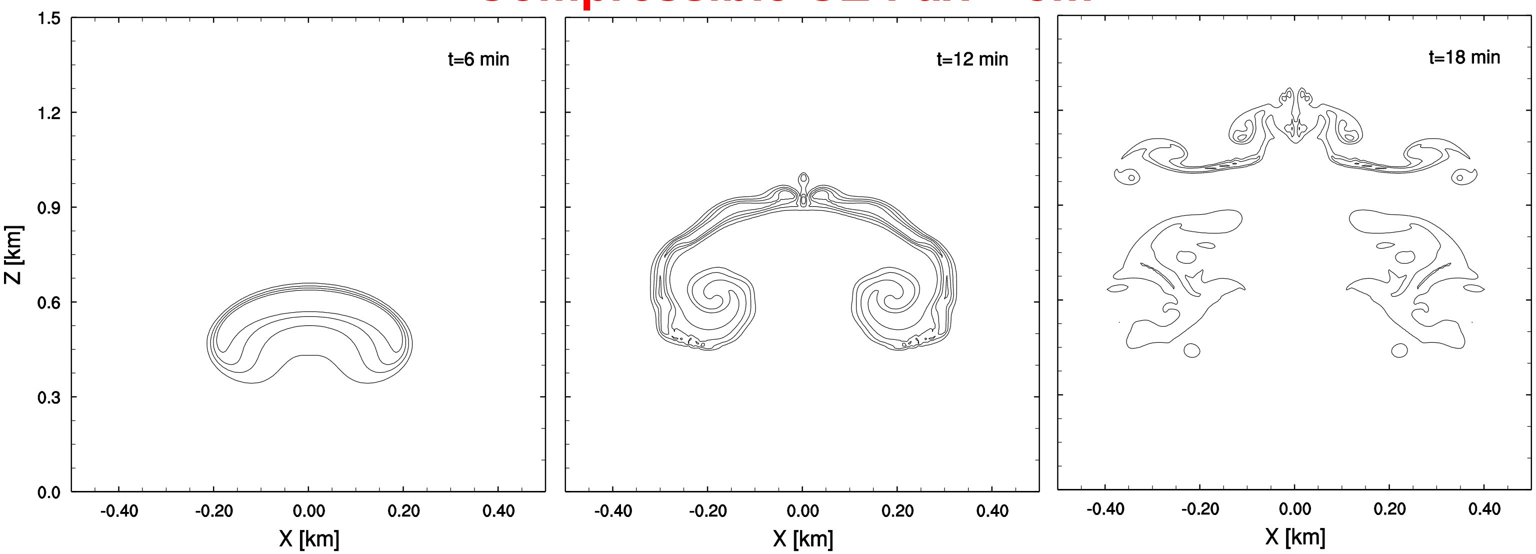
Both COSMO-EULAG cores provide comparable solutions.

Time evolution of the warm bubble – tests at different resolutions

Compressible CE : dx = 10m



Compressible CE : dx = 5m

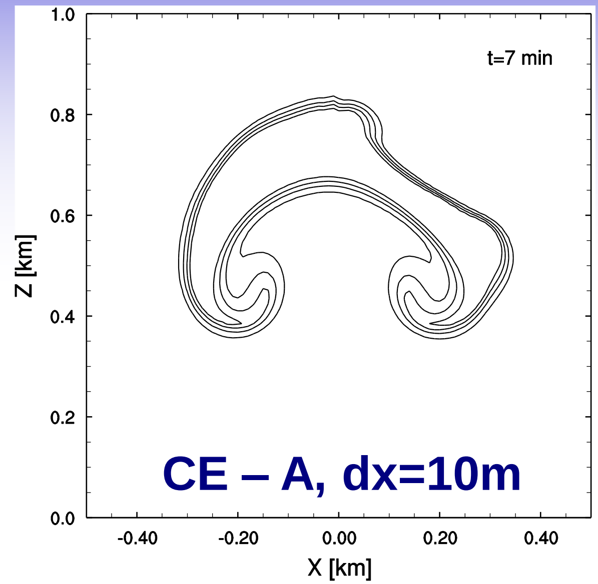


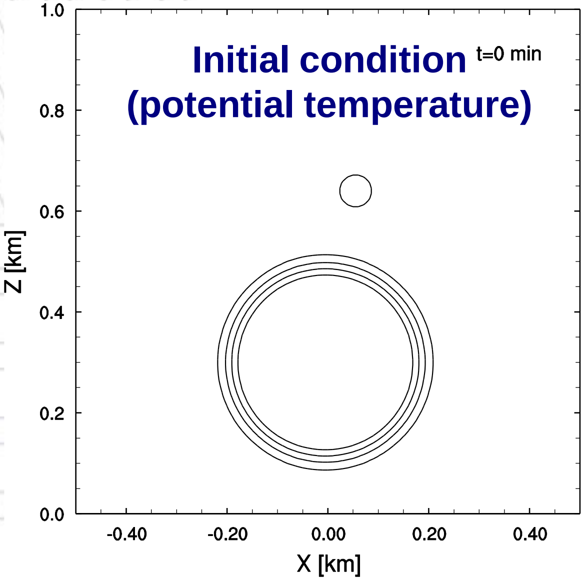
Larger resolution together with shorter time-step size allow to resolve more small scale structures (vortices).

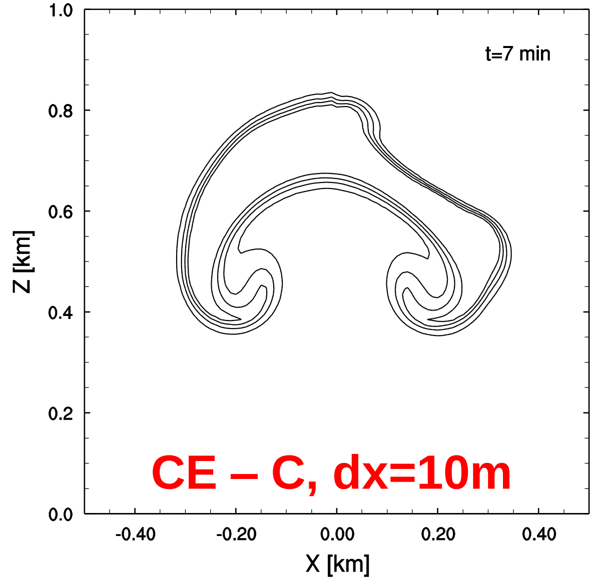
Large- and small-scale thermal interaction

Experiment no 2 :

- L_x=1 km, L_z=1 km
- ΔT_{warm}=0.5 K and ΔT_{cold}=-0.15 K
- r_{warm}=250 m and r_{cold}=50 m



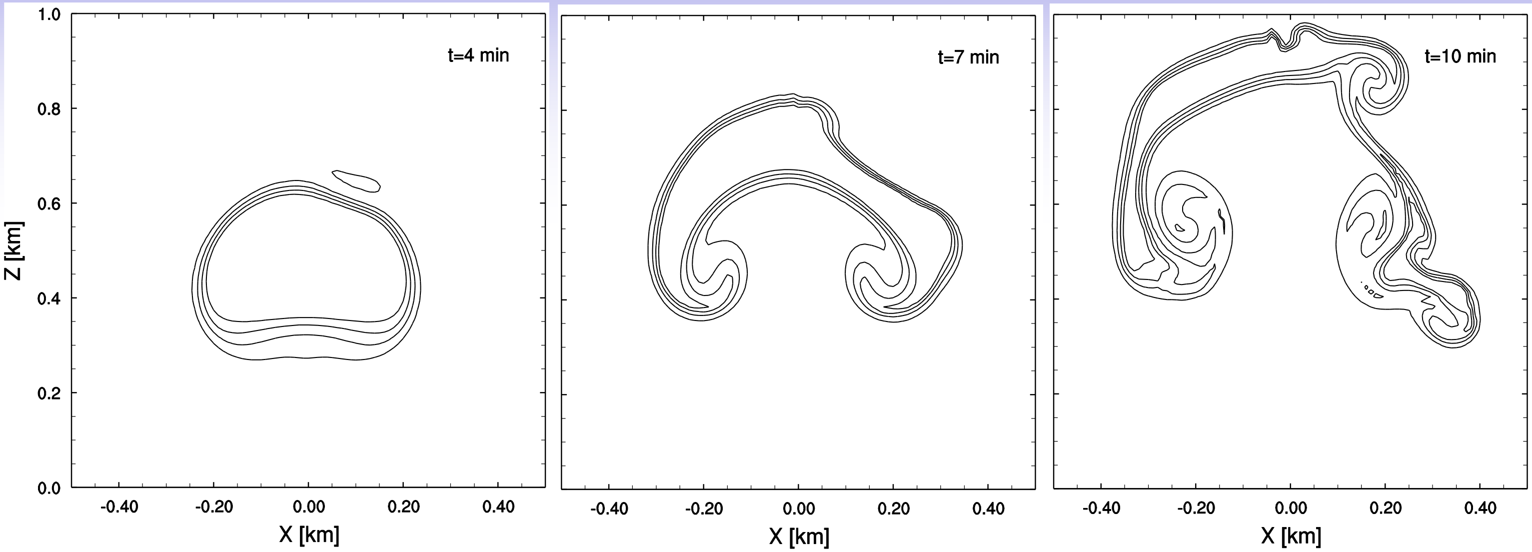




Both COSMO-EULAG cores provide comparable solutions.

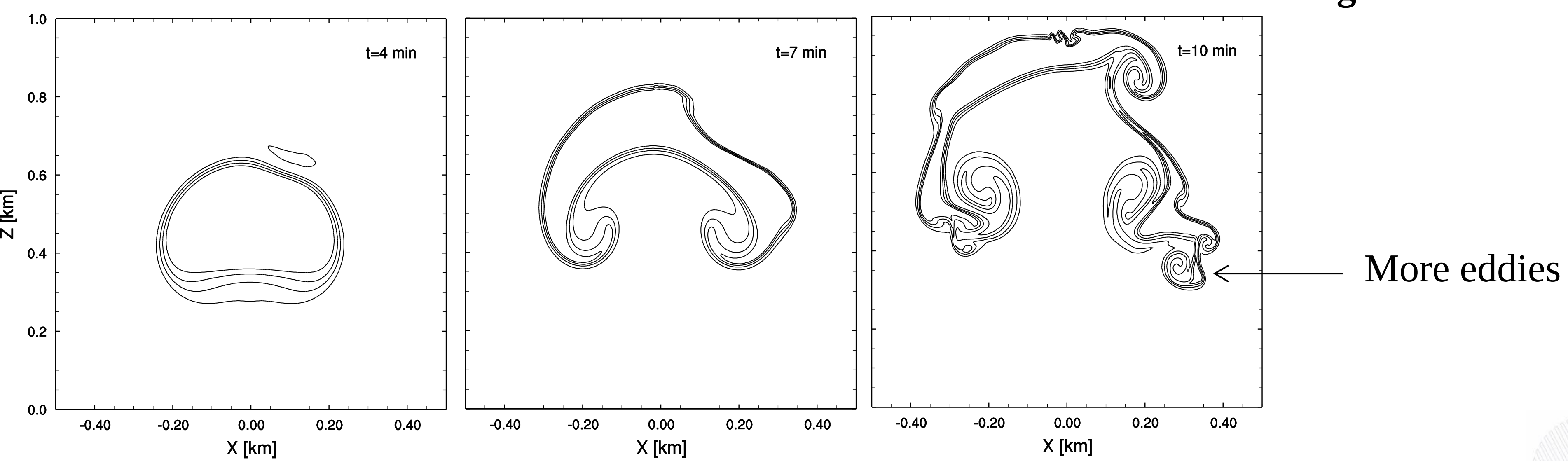
Effect of mesh resolution – test of compressible dynamical core

Compressible CE : dx = 10m



The small cold bubble determines the size of eddies up to around 7th minute of integration.

Compressible CE : dx = 5m



Later, when the cold thermal is diffused, smaller vortices start to develop in simulations at larger resolution.

CONCLUSIONS

- Results of the dry idealized tests obtained using both compressible and anelastic dynamical cores are in good qualitative and quantitative agreement
- The solutions are also in agreement with reference (published) results.

Documentation

Convection-permitting regional weather modeling with COSMO-EULAG: Compressible and anelastic solutions for a typical westerly flow over the Alps

Marcin J. Kurowski, Damian K. Wójcik, Michal Z. Ziemianski,
Bogdan Rosa and Zbigniew P. Piotrowski

Monthly Weather Review 2016
doi:10.1175/MWR-D-15-0264.1, in press

Z. P. Piotrowski report on
"Lowest (0 m)mass level of the EULAG dynamical core"