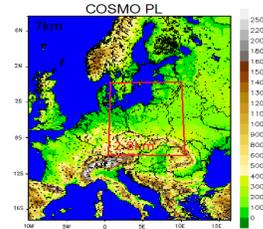


## Status of the operational suite & Computing system

### Operational suite

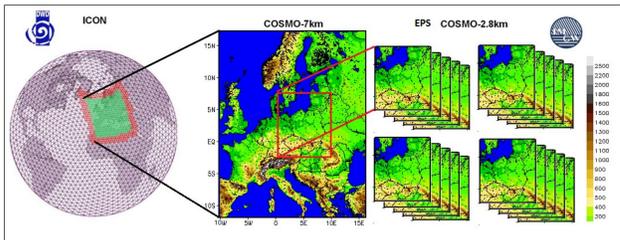


Horizontal Grid Spacing [km]	7	2.8	2.8 EPS
Domain Size [grid points]	415 x 445	380 x 405	
Time Step [sec]	40	20	
Forecast Range [h]	78	36	
Initial Time of Model Runs [UTC]	00 06 12 18		
Model Version Run	5.01		
Model providing LBC data	ICON	COSMO PL 7	
LBC update interval [h]	3h	1h	
Data Assimilation Scheme	Nudging		

### LINUX CLUSTER „Grad”

- 4 cassette systems c7000
- 145 servers BL460c Gen8
- 128GB RAM
- 6 management nodes, 2 x 8-Core CPU
- 139 computation nodes, 2 x 10-Core CPU
- performance - HPLinpack test ~61 TFlops
- disk array HP3PARStoreServ7400 ~70TB capacity

### Ensemble Prediction System



Operational setup of EPS based on Time-Lagged IC/Bcs. Members #1-5 are ready 18h (and respectively members # 6-10 – 12h, #11-15 – 6h) before a nominal EPS start up time. Members #16-20 are finalized at the current time window - completing the whole EPS forecast

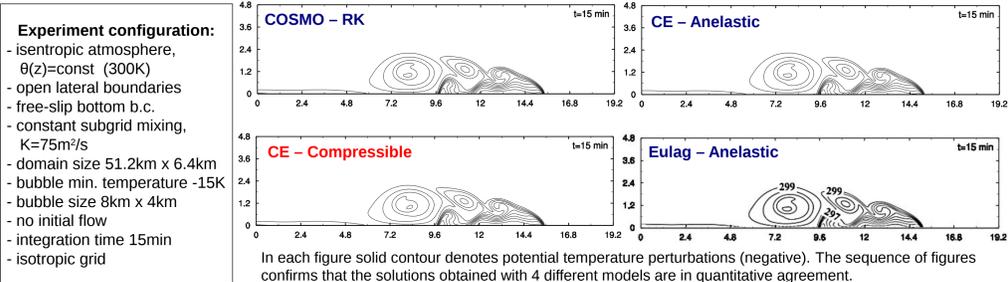
## Research & Development

### COSMO-EULAG Operationalization

Two dynamical cores of the EULAG model i.e. anelastic and compressible have been recently implemented into COSMO limited-area weather prediction model (www.cosmo-model.org) with the following motivation: i) the model solves Euler equations in conservative form with high accuracy and ii) it features high numerical robustness confirmed in number of benchmark tests including applications for steep orography. Current efforts are focused on the development of compressible COSMO-EULAG. The main goal is to optimize and configure the dynamical core and its coupling with COSMO physical parameterizations in order to provide superior weather forecasts for environments supporting deep convection development.

### Idealized experiment - cold density current

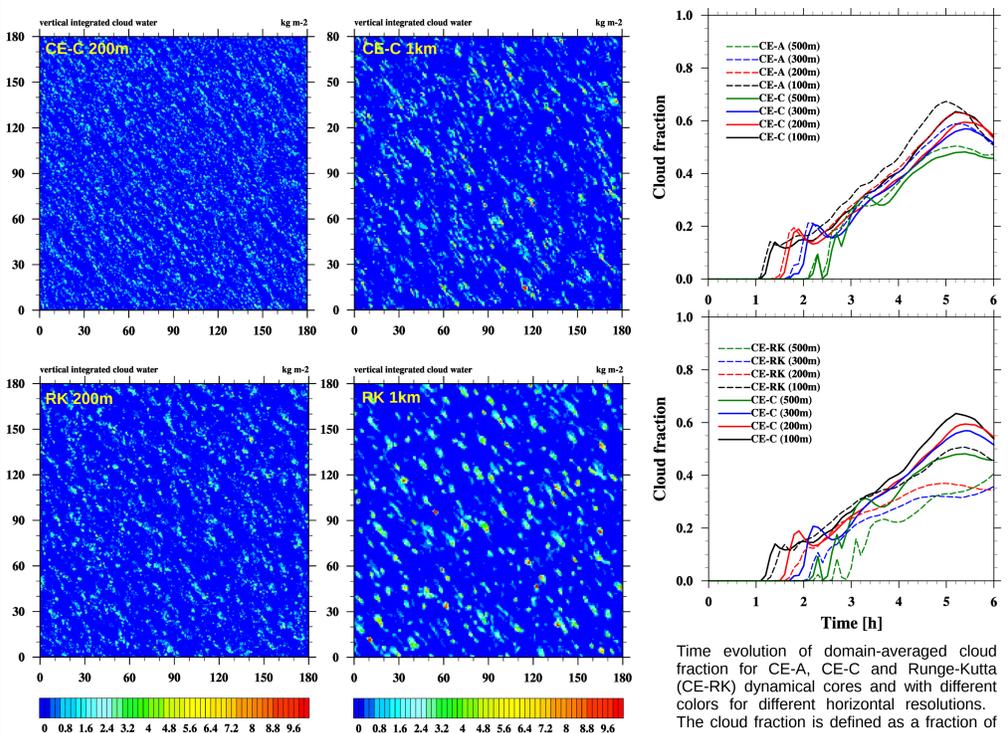
In this experiment [1] a descending blob of air in isentropic 2-dimensional atmosphere initializes spreading of the cold density current over the domain surface. During the spread, the Kelvin-Helmholtz rotors develop in the result of a shearing instability at the border between cold and warm air. High diffusion rate limits the number of rotors to three. The experiment tests capability to model nonhydrostatic non-linear flows.



In each figure solid contour denotes potential temperature perturbations (negative). The sequence of figures confirms that the solutions obtained with 4 different models are in quantitative agreement.

### Modeling of moist convection over flat terrain

Realistic simulations test a representation of convection initiation for 6h period between the sunrise and early afternoon over Amazonia [2]. The simulations were performed for varying microphysics schemes, horizontal resolutions (down to 50 m gridlength), 1-d and 3-d turbulence schemes for COSMO model with EULAG (compressible: CE-C and anelastic CE-A) and with reference Runge-Kutta (RK) dynamical cores.



Vertically integrated cloud water at t = 6h for 200 and 1000m horizontal grid length; top row for CE-C, bottom for RK dynamical cores.

### Conclusions:

- Results from high-resolution simulations with the three dynamical cores are in qualitative agreement with the reference solution Grabowski et al. 2006.
- Formation of precipitation in simulations with CE-A/C is slightly faster than in CE-RK (depends on the mesh resolution).
- The characteristics of cloud field and precipitation (as the amount, onset, evolution and temporal structure of precipitation) strongly depend on microphysics parameterization scheme (not shown here)
- General characteristics of cloud field and precipitation strongly depend on horizontal resolution with clouds and precipitation developing consistently earlier for higher model resolutions.
- Dependence of precipitation rate on turbulence scheme (for 500m resolution) differs for dynamical cores, applied, and is relatively small for EULAG (except Kessler scheme) and more pronounced for RK.

References:  
 [1] Straka, J. M., R. B. Wilhelmson, L. J. Wicker, J. A. Anderson, and K. K. Droegemeier 1993 Int. J. for Num. Meth. in Fluids vol. 17 p. 1-22  
 [2] Grabowski, W. W., P. Bechtold, A. Cheng et al., 2006: Daytime convective development over land: A model intercomparison based on LBA observations. Q.J.R. Meteorol. Soc., 132, 317-344.

## Research & Development

### EPS-based tornado forecasting

Worldwide, there have been numerous observational case studies analyzing the mesoscale environment of tornadic supercells. These studies pointed out that mesoscale characteristics of the wind field, altered by horizontal boundaries such as thermal or moisture horizontal gradients, can be supportive of tornado occurrence. The main aim of the study was to analyze the thermodynamic and kinematic parameters derived from soundings and formulate an UTI (Universal Tornado Index) index to forecast a severe convection events.

$$UTI = \frac{CAPE - SRH_{1km}}{1000} + \frac{5 \cdot (DLS - 20) + \frac{200 - LCL}{10}}{100} + \frac{CAPE_{2km} + SRH_{1km}}{4} + \frac{LLS \cdot AMR_{500}}{12 \cdot 100}$$

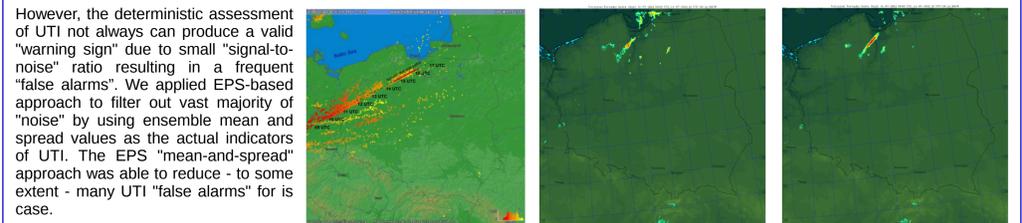
where: CAPE - surface based Convective Available Potential Energy.  
 CAPE<sub>2km</sub> - surface based CAPE released below 3km agl.  
 LCL - surface based lifting condensation level height agl.  
 AMR<sub>500</sub> - average mixing ratio below 500m agl.  
 LLS - 0-1km, DLS - 0-6km wind shear (magnitude of vector difference)  
 SRH1km - 0-1km storm relative helicity

The values of UTI increase together with an increasing probability for a significant tornado.

If SRH<sub>1km</sub> is less than 0, SRH<sub>1km</sub> become equal to 0, similarly, if LCL is greater than 1500m or CAPE is equal to 0 (or convection precipitation is less than 2mm/h) then UTI=0

### Case study – 14.07.2012

UTI distinguishes between tornadic and no-tornadic environments and detects warm as well as cold tornado cases. The values of UTI increase together with an increasing probability for a significant tornado. The quality of this approach was shown for a case 14 July 2012 (one of the strongest of lately reported incidents), when a shortwave trough with a cold front passed through Poland. A few tornadoes were reported in the north central part of the country within an isolated cyclic supercell. The cell moved along the thermal and moisture horizontal gradients with the support of a synoptic scale lift, resulting in four tornado damage tracks in a distance of 100km and with a total length of 60km.

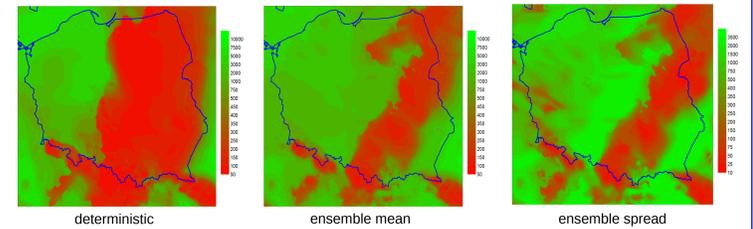


Dashed line – radar-based time and position of the thunderstorm. Red line indicates tornado damage paths. Lightning captured by the lightning detection network 0600-1800 UTC

### EPS-based fog and visibility range forecasting

Another example of operational use of EPS in a convection-permitting scale is an assessment of visibility (VIS) range [3]. The input parameters includes cloud water mixing ratio(s), rain water, water vapor, air temperature and pressure together with precipitation amount, and a visual range as an output value. The routine calculates an extinction coefficient, beta [km<sup>-1</sup>], in a general form of β=a·b<sup>n</sup> with a and α – constants, and b being a general function of an amount of water in the air. The extinction coefficient for each water species is calculated, and then all applicable β are summed to yield a single β value. Then the following relationship is used to determine visibility VIS=1/β ln(ε) [km] where ε is the threshold of contrast, usually taken to be 0.02.

This procedure was first developed by Stoelinga and Warner [4], but now, all values of parameters needed for estimation of VIS were calculated as a EPS-based forecast, then presented as ensemble mean (center panel) and ensemble spread (right panel) of VIS.



References:  
 [3] Kunkel, B.A. 1984: Parameterization of Droplet Terminal Velocity and Extinction Coefficient in Fog Models. Journal of Climate and Applied Meteorology, 23, 34-41.  
 J. Zhang, H. Xue, Z. Deng, N. Ma, C. Zhao, Q. Zhang 2014: A comparison of the parameterization schemes of fog visibility using the in-situ measurements in the North China Plain. Atmos. Env. 92, 44-50  
 [4] Stoelinga MT, Warner TT. 999. Nonhydrostatic, mesobeta-scale model simulations of cloud ceiling and visibility for an East Coast winter precipitation event. J. Appl. Meteorol.38: 385 – 404

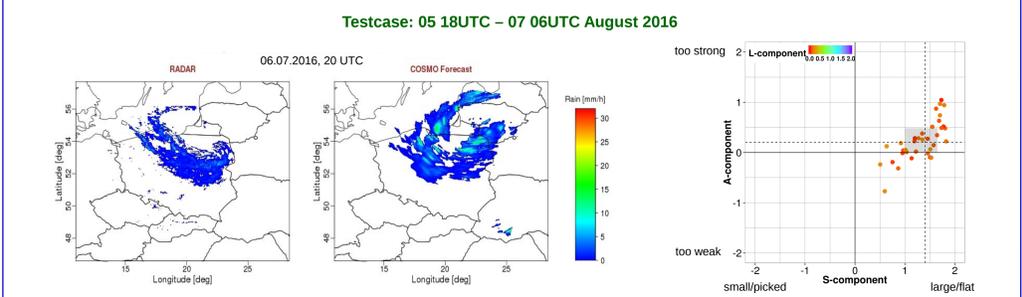
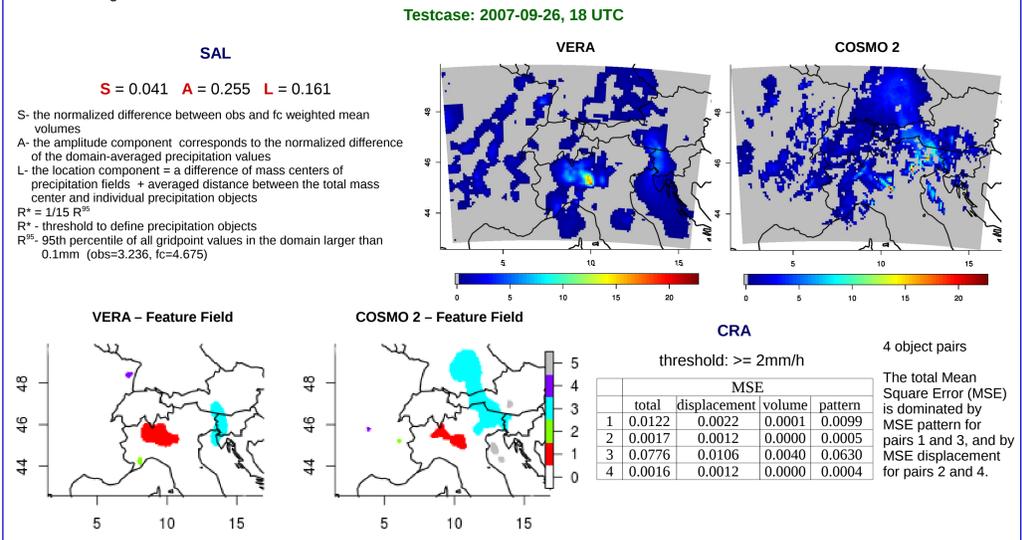
### Intercomparison of Spatial Verification Methods for COSMO Terrain – PP INSPECT

Spatial Verification methods are newly proposed for verifying high resolutions models. These methods often do not require one-to-one matches between forecast and observed events at the grid scale in order to give credit to a good forecast [5]. Priority Project INSPECT is dedicated to apply the spatial verification methods (following MesoVICT project activities [6]) to deterministic and EPS COSMO forecasting systems. One of the goals of INSPECT project is providing a set of guidelines to facilitate decision-making about which methods can be the best suited to particular applications.

### Structure Amplitude Location (SAL) and Contiguous Rain Area (CRA)

SAL is a feature-based quality measure which provides information about the structure, amplitude, and location of a quantitative precipitation forecast in a prespecified domain [7]. To compute the location and structure components, at first a identification of individual precipitation objects within the considered domain (separately for the observed and forecast fields) is required. A forecast is perfect if S = A = L = 0. A contiguous rain area is defined as a region bounded by a user-specified isohyet (rain rate contour) in the forecast and/or the observations [8]. It is the union of the forecast and observed entities (blobs). CRA verification uses pattern matching techniques to determine the location error, as well as errors in area, mean and maximum intensity, and spatial pattern. The total error can be decomposed into components due to location, volume, and pattern error.

The results of spatial verification object oriented methods applied to 1h accumulated precipitation COSMO 2 (MeteoSwiss) and COSMO PL 2.8 model outputs are presented below. COSMO 2 was verified against Vienna Enhanced Resolution Analysis data (VERA), COSMO PL 2.8 was verified against radar data.



References:  
 [5] Ahijevych, D., E. Gilleland, B.G. Brown, and E.E. Ebert, 2009: Application of spatial verification methods to idealized and NWP-gridded precipitation forecasts. Wea. Forecasting, 24 (6), 1485-1497, DOI: 10.1175/2009WAF2222298.179-20.2.  
 [6] https://www.ral.ucar.edu/projects/icp/  
 [7] Wernli, H., C. Hofmann, and M. Zimmer, 2009: Spatial forecast verification methods intercomparison project: Application of the SAL technique. Wea. Forecasting, 24 (6), 1472-1484, DOI: 10.1175/2009WAF2222271.1.  
 [8] Ebert, E. E., and J. L. McBride, 2000: Verification of precipitation in weather systems: Determination of systematic errors. J. Hydrol., 239, 1