Numerical Weather Prediction at IMGW-PIB

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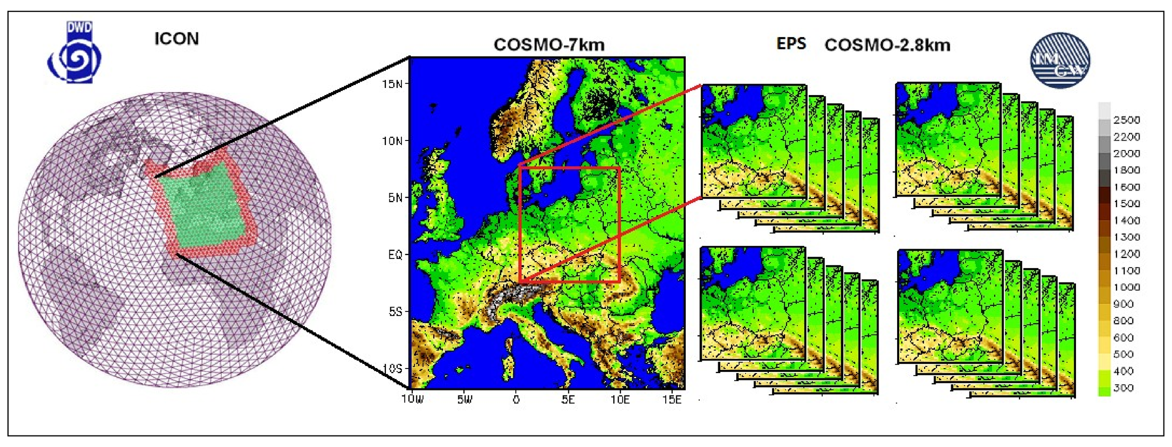
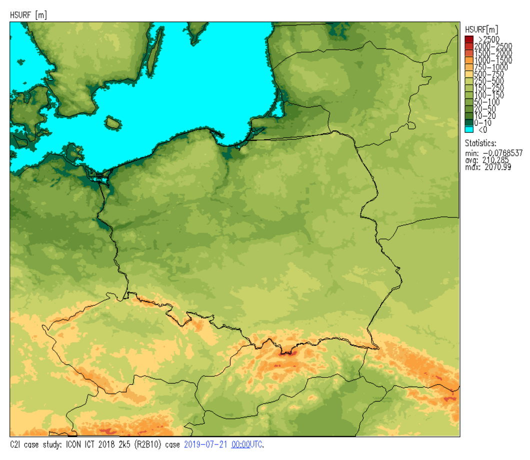
Status of the operational suite

Operational – COSMO

Semi Operational – ICON PL





Model	COSMO PL 7	COSMO-CE PL	COSMO PL - TLE
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]	86	48	
Initial Time of Model Runs [UTC]	00 06 12 18		
Data Assimilation Scheme	Nudging		None
Model Version Run	5.05		
Model providing LBC data	ICON	COSMO PL 7	
LBC update interval [h]	3h	1h	

In June 2020 IMGW-PIB made a change to the operational model replacing COSMO PL 2.8 (version 5.01) with its Runge Kutta dynamical core with COSMO-CE PL 2.8 (version 5.05) which has the EULAG dynamical core.

ICON PL setup

- Equivalent surface resolution ~2.5km
- 12x12deg corresponding to COSMO-PL (2.8km, rotated: NP -170.0,40.0)
- 294'636 elements, R2B10
- 65 vertical levels
- Time step: dt=24s
- Forecast range: 48h
- Initial time of model run: 00, 12 UTC
- No data assimilation scheme
- LBC data provided from ICON
- 3h LBC Update interval

Appraisal of "Challenging WeAther" FoREcasts COSMO Prority Project AWARE

High impact weather events such as extreme temperatures, heavy precipitation, lightning, fog, wind gust can cause significant disruption effecting sectors such as health, transport, agriculture and energy. Providing an accurate forecast of extreme weather is very important and raises a question which verification methods can be objectively used. There is no single verification metric which is superior to all others. Each metric has its strengths and weaknesses and so a combination of metrics is often used to best understand the performance of the modeling system. Examples of metrics that can be used include: SAL (Wernli et al., 2008), FSS (Roberts and Lean 2008, Blaylock and Horel, 2020) and Neighborhood-based approaches / Coverage–Distance–Intensity (CDI) verification (Wilkinson, 2017).

The goal of PP AWARE project is to try out a number of forecast methods and evaluation approaches that are linked to high impact weather (not necessarily considered extreme to all users) and to provide COSMO Community with an overview and recommendations as to how challenging weather/high impact weather situations should be handled.

At IMGW-PIB challenging weather and high impact weather were the subject of interest and cooperation with road maintenance and aviation services. Starting from 2004, collaboration with the road maintenance services resulted in procedures of forecast of fog (or visibility range, VR), road icing (esp. occurrence of "black ice") and intensive precipitation of snow, also in coincidence with strong wind that can blow snow on the road. As far as the aviation services are concerned, IMGW-PIB cooperates with PAZP (National Aviation Agency). This cooperation includes – among others – forecasts of wind shear, runway visibility range (RVR), thunderstorms etc. The information delivered to PAZP contains not only absolute values, but also the probabilities (Bayesian approach) of occurrence of certain phenomena.

Verification of Lightning forecast – case study

Observations: lightnings (cloud-to-ground , cloud-to-cloud) from the Polish lightning detection system PERUN, covering Poland + parts of neighbouring countries

Forecast: Flash Rate - CAPE based index (COSMO PL 2.8), calculated as follows:

$$W = 0.3 \cdot \sqrt{2 \cdot CAPE}$$

$$FR = \left(\frac{W}{14.66}\right)^{4.54}$$

$$if \quad CTT > -15^{\circ}C \quad FR = FR \cdot \left[\max\left(\frac{-CTT}{15}, 0.01\right)\right]$$

$$if \quad CBT < -5^{\circ}C \quad FR = FR \cdot \left[\max\left(\frac{CBT+15}{10}, 0.01\right)\right]$$

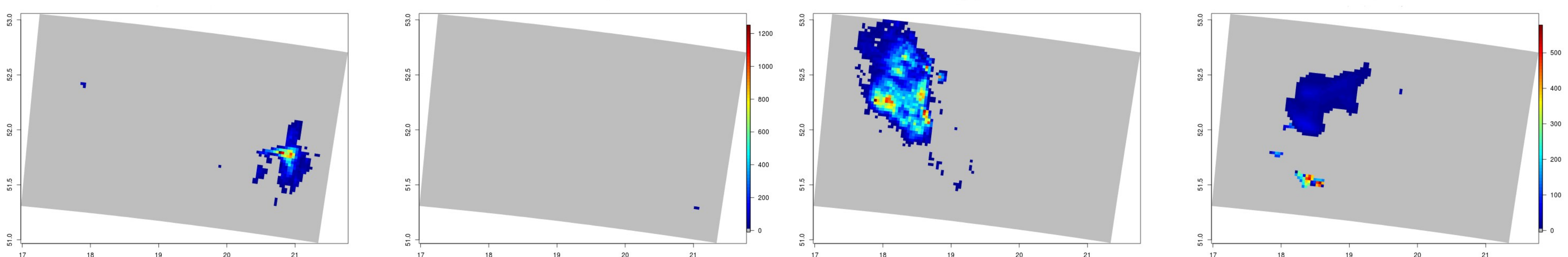
Where: *W* - updraft velocity
CTT - cloud top temperature
CBT - cloud bottom temperature

The cases selection:
- For both observations and forecasts
FR max_value (over the entire domain) > 20 strikes/hour
- A duration of the storm must be longer than 6 hours
- Period: 2011-2017

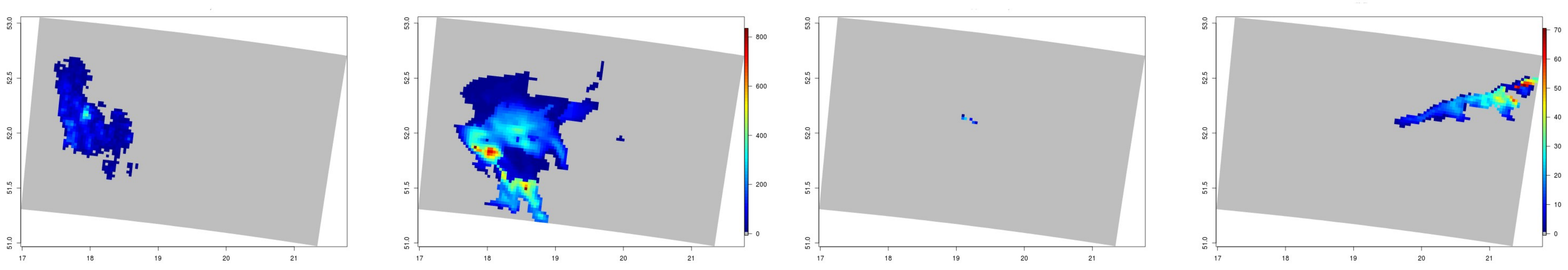
Verification methods such as SAL, FSS, Categorical analysis (Contingency tables and predictands), Standard evaluation at the grid scale and Cross- (space-lag) correlation approach were applied.

Below the examples of selected missed, underestimated, overestimated and false forecasts of spatial distribution of lightnings and results of FSS application for the worst (2015), the best (2013) year and a mean for the entire period of 2011-2017.

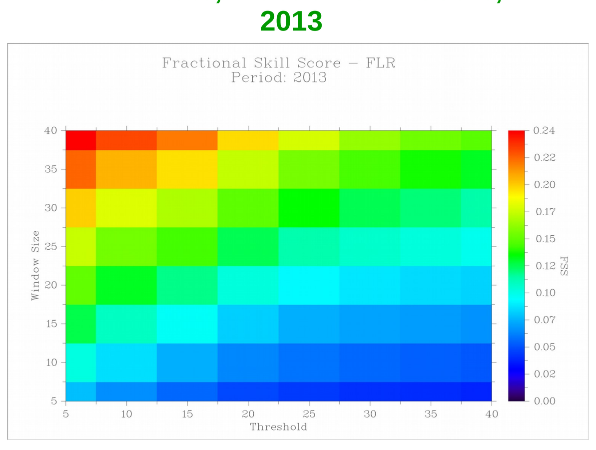
Totally missed forecast — PERUN, COSMO PL 2.8
Underestimated forecast — PERUN, COSMO PL 2.8



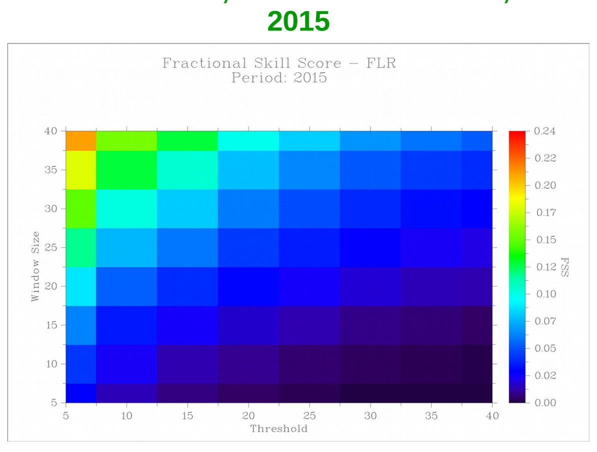
Overestimated forecast — PERUN, COSMO PL 2.8
Totally false forecast — PERUN, COSMO PL 2.8



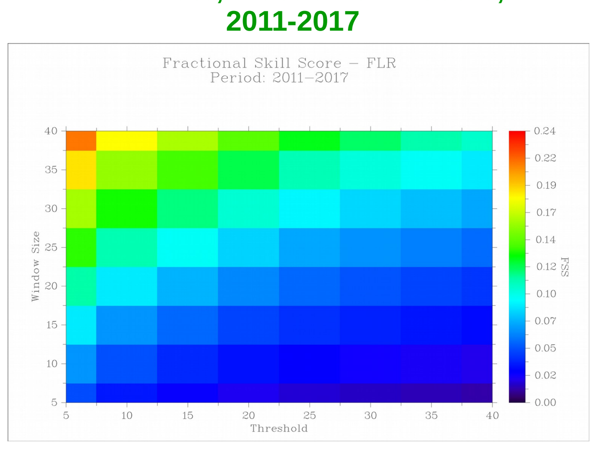
Flash Rate, Fraction Skill Score, 2013



Flash Rate, Fraction Skill Score, 2015



Flash Rate, Fraction Skill Score, 2011-2017



Analysis of the whole selected period 2011-2017 suggests that the parametrization of the Flash Rate based on the model CAPE generally overestimates the parameter compared to the observations. The FSS values are relatively small. Further work is planned to improve the Flash Rate parameterization and verify the results obtained in this way, accordingly.

References:
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2. Roberts, N. M., and H. W. Lean, 2008: Scale-Selective Verification of Rainfall Accumulations from High-Resolution Forecasts of Convective Events. Mon. Wea. Rev., 136, 78–97.
3 Blaylock, B. K., and J. D. Horel, 2020: Comparison of Lightning Forecasts from the High-Resolution Rapid Refresh Model to Geostationary Lightning Mapper Observations. Wea. Forecasting, 35, 401–416.
4. Wilkinson, J. M., 2017: A Technique for Verification of Convection-Permitting NWP Model Deterministic Forecasts of Lightning Activity. Wea. Forecasting, 32, 97–115.

Research & Development

COSMO-EULAG for very high resolutions over the Alps

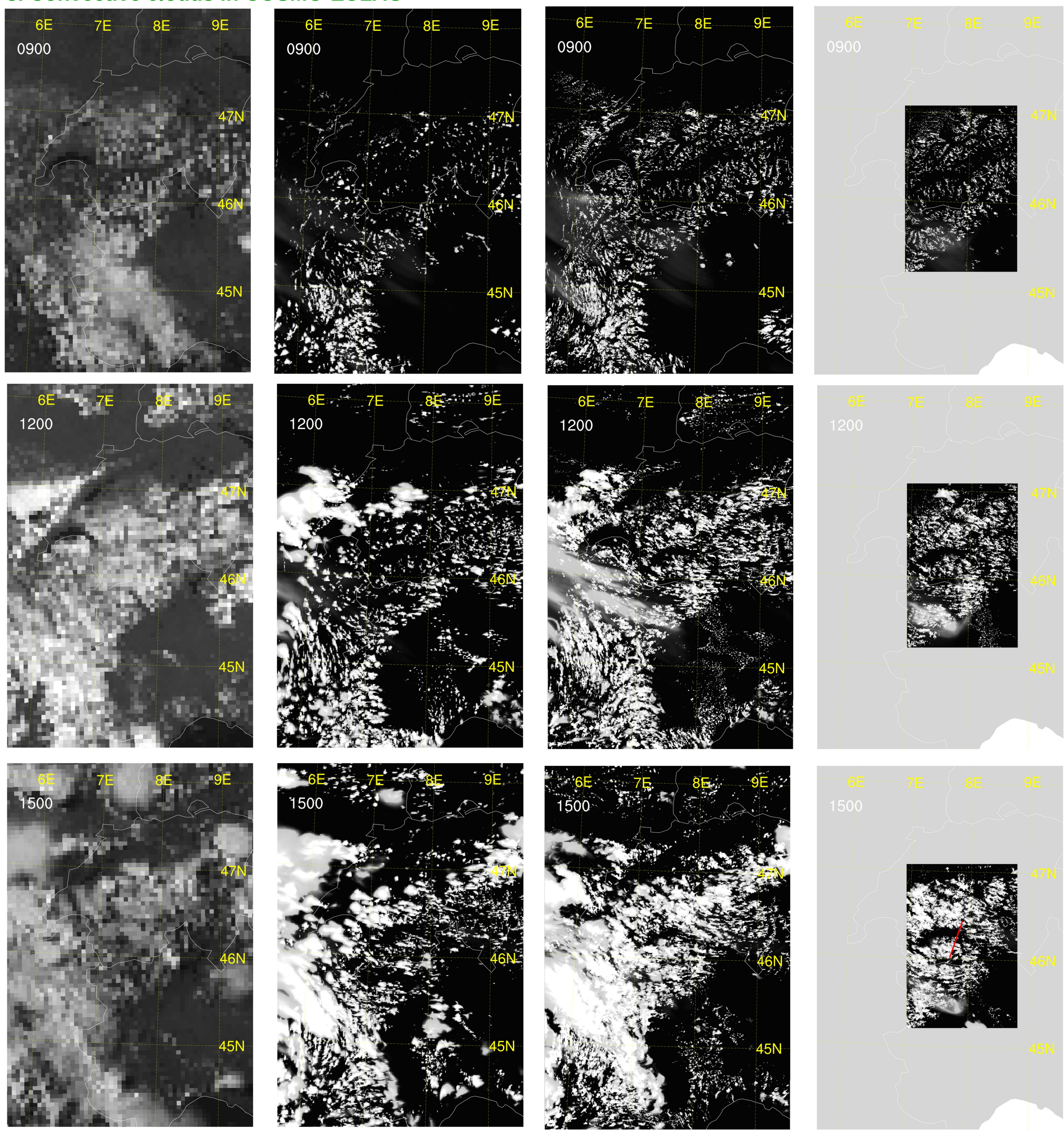
1. Introduction

A new version of the COSMO model employing EULAG dynamical core, called COSMO-EULAG, was developed at IMGW-PIB for convection-permitting NWP applications within the Priority Projects CDC and CELO of the COSMO consortium. The compressible non-hydrostatic dynamical core of EULAG is semi-implicit allowing for long time steps bounded by CFL condition for meteorological flows (Smolarkiewicz et al. 2014, Kurowski et al. 2014, Smolarkiewicz et al. 2016). The EULAG dynamical core is linked with physical parameterizations and infrastructure of the COSMO model version 5.05. Since June 2020 the model routinely provides an operational numerical weather forecast for Poland.

2. High-resolution COSMO-EULAG over the Alps

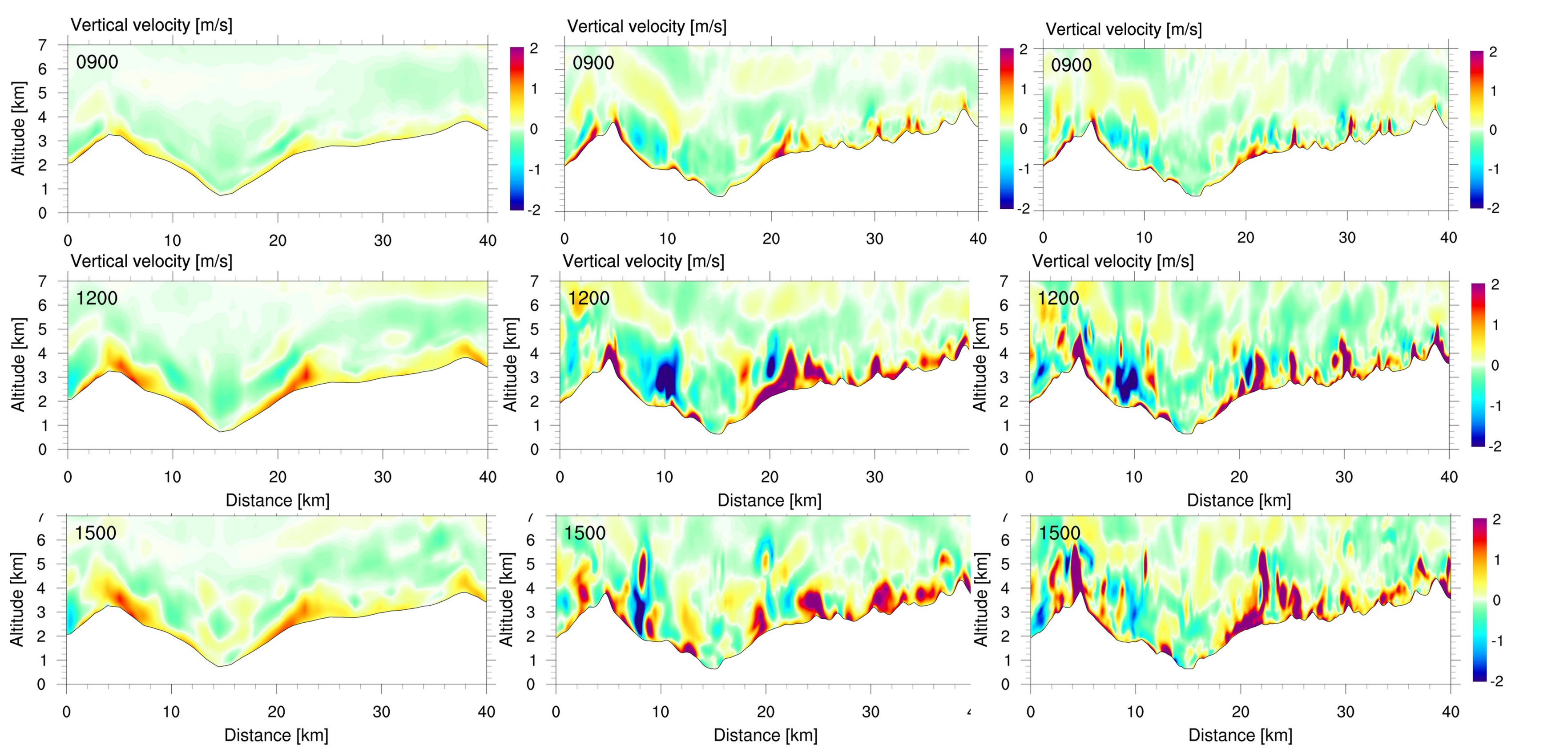
The operational version of COSMO-EULAG was tested for very-high resolution representations of the Alpine flow. The case study of summer day-time convection developing within weak flow regime on 19 July 2013 was performed. The model uses 60 vertical levels and the experiments are performed with the horizontal grids of 2.2, 1.1, 0.55, 0.22, and 0.1 km. For 2.2, 1.1 and 0.55 km grids the standard MeteoSwiss operational domain with standard BC and IC is used. For 0.22 and 0.1 km grids the domains are smaller and the IC and BC are taken from the simulation at 0.55 km grid. For simulations at 2.2, 1.1, and 0.55 km grid a standard TKE turbulence parameterization (Raschendorfer 2001) is used. The experiments at 0.22 and 0.1 km employ the Smagorinsky turbulence scheme (Baldauf and Brdar 2016).

3. Convective clouds in COSMO-EULAG



The evolution of the cloud field from Meteosat HRV observations (left) and CE simulations at 1.1 km (midddle left), 0.22 km (middle right), and 0.1 km (right) grid shown in the domain of the 0.22 km grid simulation; top row for 0900 UTC, middle for 1200 UTC, and bottom for 1500 UTC. The model clouds are represented by vertically integrated condensate including cloud water, ice, snow, and groupel.

3. Vertical velocity in COSMO-EULAG



The vertical cross section through the vertical velocity between Bietschhorn (left) and Weisshorn (right, see the red line in the figure of CE clouds at 0.1 km grid at 1500 UTC). The CE results are shown for 1.1 km grid (left), 0.22 km grid (middle) and 0.1 km grid (right).
The vertical velocities on the figure reach -3.5 to 6.5 m/s at 0.22 and 0.1 km grids, in agreement with observations for typical convective mountain flows (Raymond and Wilkening 1982). The maximum slopes' inclinations are 34, 74 and 85 degrees in computational domains at 1.1, 0.22, and 0.1 km grid, respectively.

4. Summary

- The COSMO-EULAG demonstrated strong numerical robustness and correct dynamics-physics coupling for very-high resolution forecasts over complex orography.
- Very high resolutions lead to better representations of the convective cloud field (of larger density), especially at the convection initiation, and to more realistic representation of the vertical velocity distribution (in terms of its pattern and amplitudes).
- The EULAG dynamical core is ready for convective-scale operational applications over complex orographies at horizontal grids as small as 100 m, and slopes' inclinations as large as 85 degrees, and likely beyond that limits.

References:
1. Baldauf, M., S. Brdar, 2016, 3D diffusion in the terrain-following coordinates: testing and stability of horizontally explicit, vertically implicit discretization. Quart. J. Roy. Meteor. Soc., 142, 2087-2101.
2. Kurowski, M.J., Smolarkiewicz, P.K., Grabowski, W.G, 2014, Anelastic and Compressible Simulations of Moist Deep Convection. J. Atmos. Sci. 71, pp. 3767-3787.
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4. Raymond D., Wikening, 1982, Flow and mixing in the New Mexico mountain cumuli. J. Atmos. Sci., 39, 2211-2228.
5. Smolarkiewicz, P.K., Kuehnlein, C., Wedi, N.P., 2014, A consistent framework for discrete integrations of soundproof and compressible PDEs of atmospheric dynamics. J. Comput. Phys. 263, pp. 185-205.
6. Smolarkiewicz, P.K., Deconinck, W., Hamrud, M., Kuehnlein, C., Mozdzynski, G., Szmelter, J., Wedi, N.P., 2016, A finite-volume module for simulating global all-scale atmospheric fows. J. Comput. Phys., 314, pp. 287-304.