Numerical Weather Prediction at IMGW-PIB

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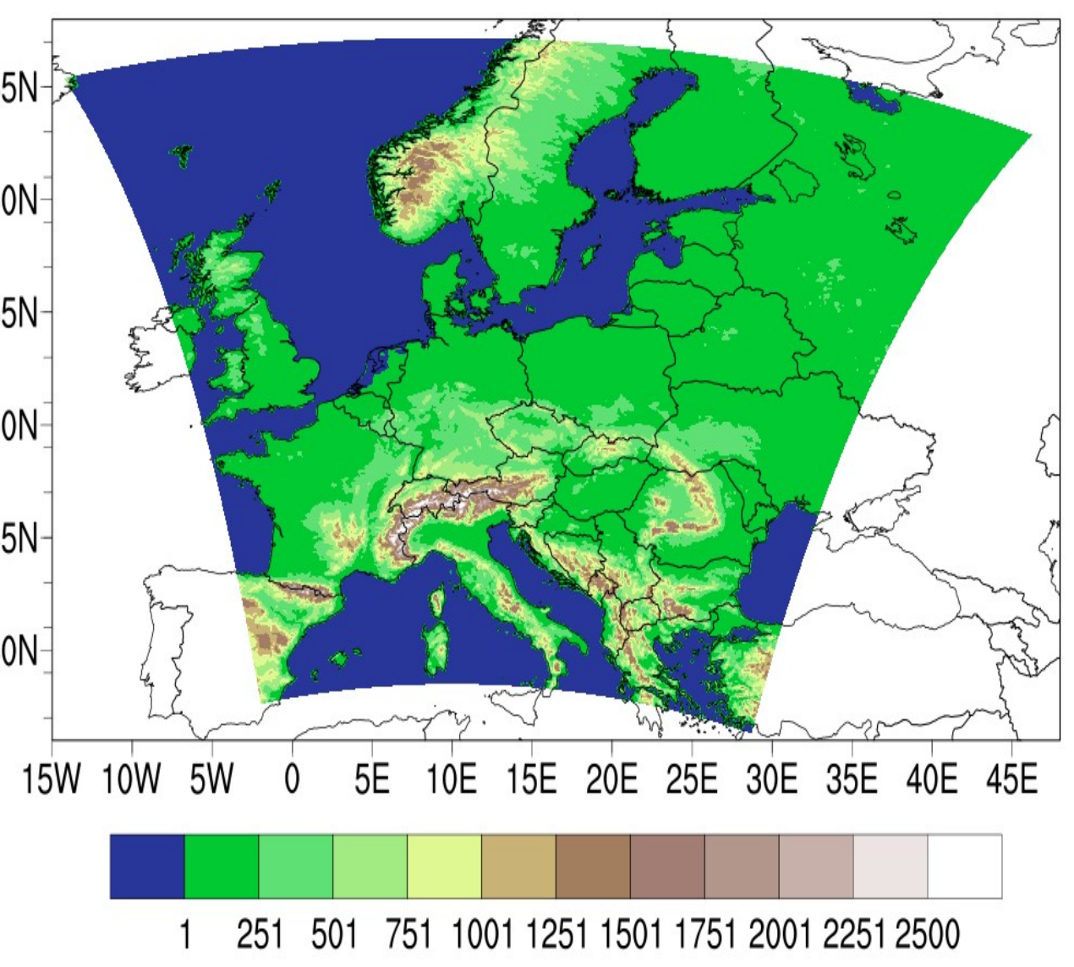
Status of the operational suite

Operational – COSMO

COSMO PL 7



COSMO PL 7

- 7 km mesh size
- Domain size [grid points]: 415 x 445
- 4 x per day up to +86 hours
  (00, 06 12,18 UTC)
- 40 sec Time Step
- LBCs: ICON,
  update interval every 3h
- Nudging Assimilation scheme
- version 5.05

COSMO-CE PL (COSMO-EULAG)

- 2.8 km mesh size
- Domain size [grid points]: 380 x 405
- 4 x per day up to +48 hours
  (00, 06 12,18 UTC)
- Time step: dt=20s
- LBCs: COSMO-PL 7,
  update interval 1h
- Nudging Assimilation scheme
- version 5.05

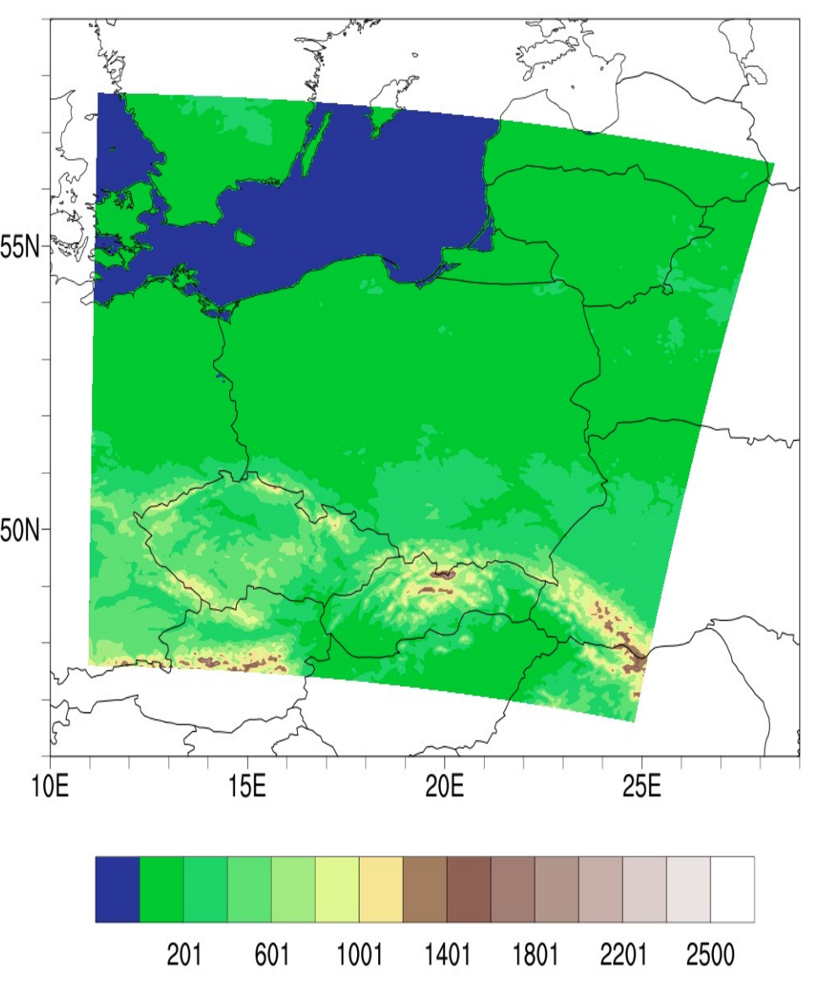
COSMO PL – TLE (ensemble)

- 20 members at 2.8 km mesh size
- Domain size [grid points]: 380 x 405
- 4 x per day up to +48 hours
  (00, 06 12,18 UTC)
- Time step: dt=20s
- LBCs: COSMO-PL 7,
  update interval 1h
- No data assimilation scheme
- version 5.05

COSMO-CE PL (COSMO-EULAG) and COSMO PL - TLE (ensemble) have the same domain size as ICON-PL

Semi Operational – ICON PL

ICON PL



ICON PL

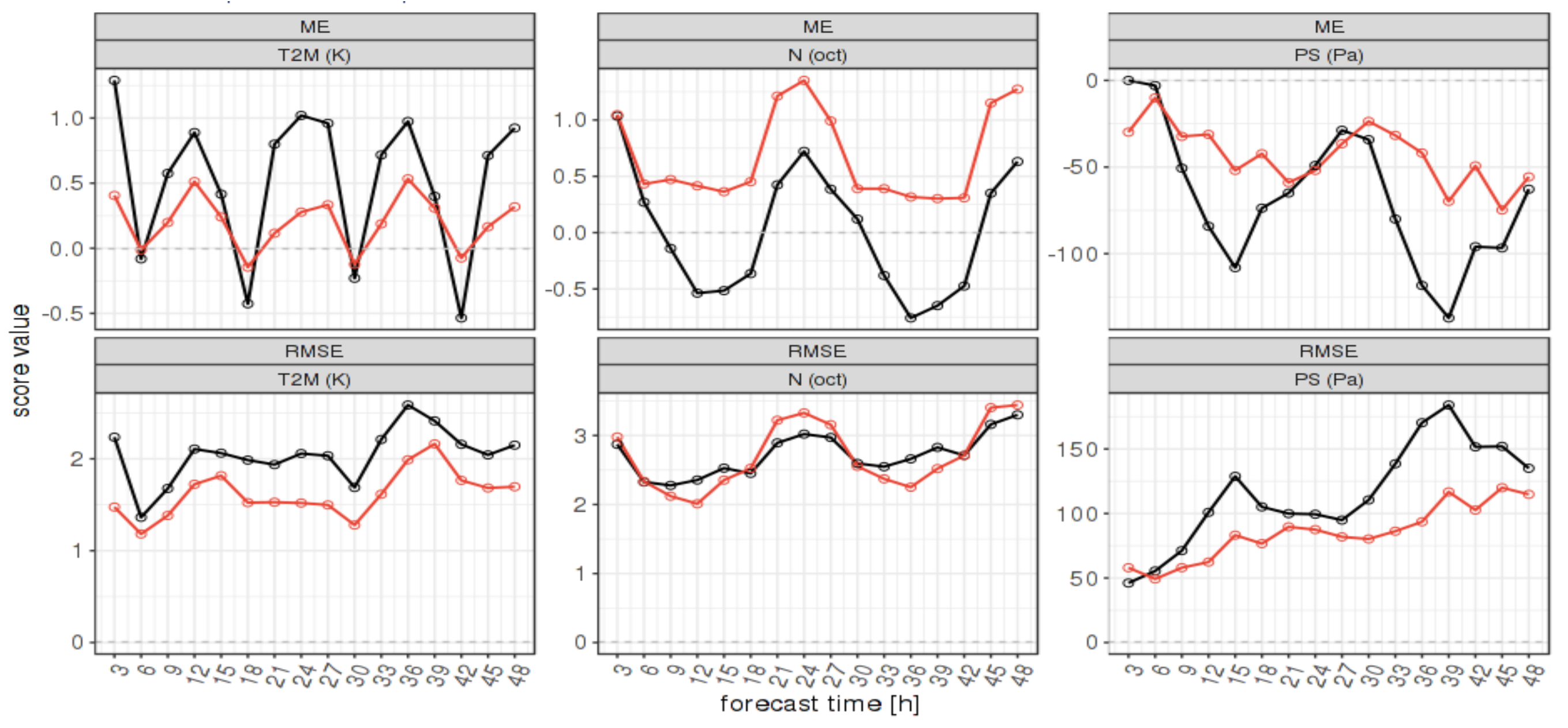
- Equivalent surface resolution ~2.5 km
- 12x12 deg corresponding to COSMO PL
  (2.8km, rotated :NP -170.0, 40.0)
- 65 vertical levels
- 2 x per day up to +48 hours
  (00, 12 UTC)
- Time step: dt=24s
- LBCs: ICON, update interval 3h
- No data assimilation scheme
- version 2.6.2.2

ICON PL and COSMO-CE PL verification results

Surface verification, All Polish SYNOP stations

ICON PL, **COSMO-CE PL,** Summer 2021, run 00 UTC

Temperature 2 m **Cloud cover** **Surface pressure**



ICON PL has more skillful diurnal cycle of 2m temperature and surface pressure than **COSMO-CE-PL**, with a reduction in mean error (ME) and Root Mean Squared Error (RMSE). **ICON PL** overestimates cloud cover throughout the forecast period, while **COSMO-CE PL** overestimates at night time and underestimates at day time. The night time overestimation is lower for **COSMO-CE PL** than for **ICON PL.**

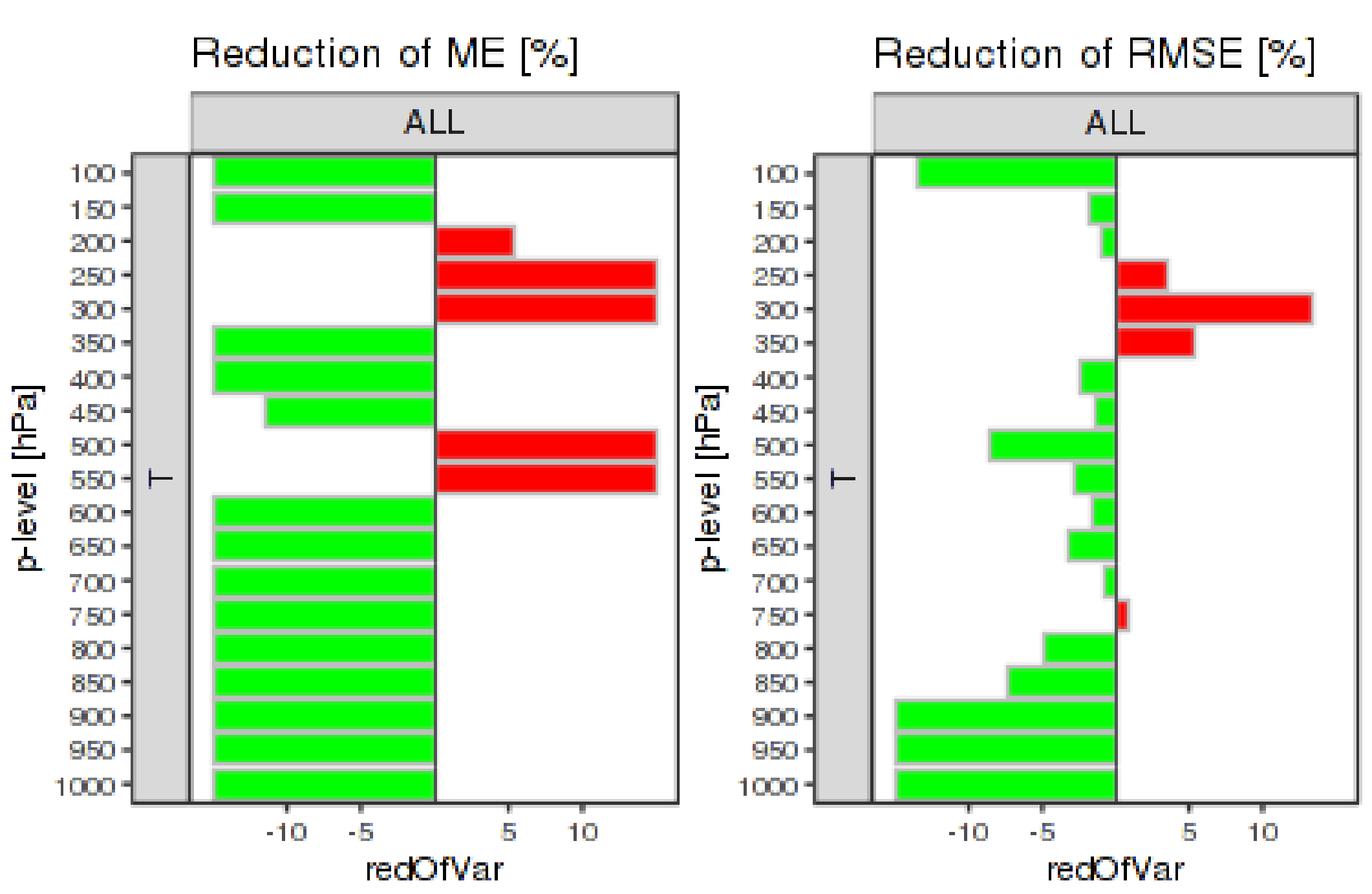
Boundary conditions for ICON-PL come directly from global ICON while for COSMO-CE come from COSMO-PL 7 model with 7 km grid.

Upper air verification, whole domain

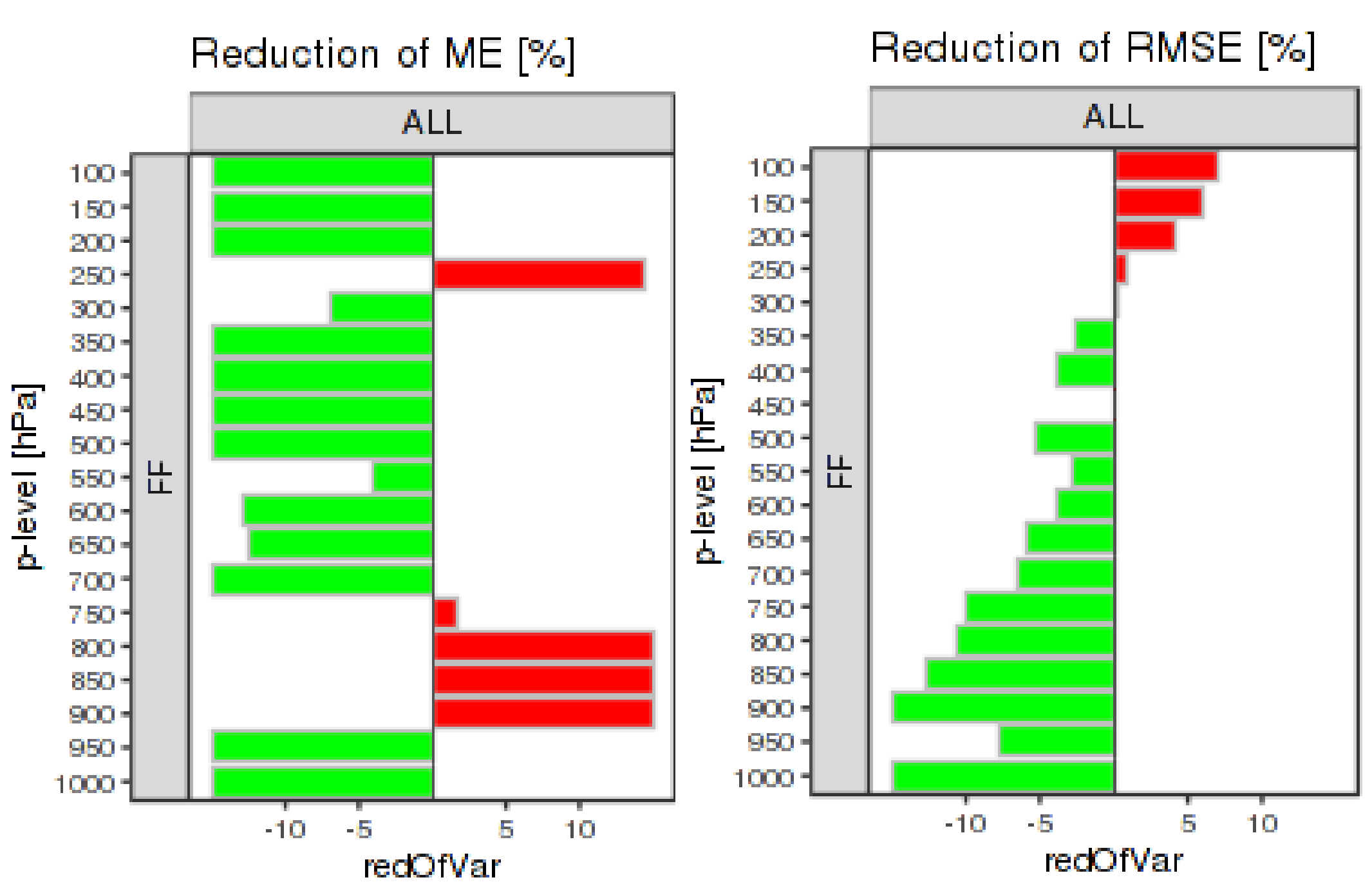
ICON-PL vs COSMO-CE-PL, Summer 2021, run 00 UTC

🟩 better 🟥 worse

Temperature



Wind speed



ICON PL has more skillful temperature than COSMO-CE PL in the lower to mid troposphere with ME and RMSE from the surface up to 600hPa. In the upper troposphere the signal is mixed with a detriment to the RMSE and ME at the 300hPa jet level.

Wind speed RMSE is reduced from the surface to 300hPa and this is accompanied by a reduction in ME except for the 750hPa-900hPa where the weak bias is exacerbated.

MachIne LEarning-based POST-processing Priority Project MILEPOST

The main goal of the Project is to provide methods of post-processing based on Machine-Learning (MLP), including Artificial Neural Networks (ANN) and other – alternative – methods.

The result of PP MILEPOST would be the examination of the relation between numerical forecast in terms of Direct Model Output (DMO) and ML-based Post-processing (MLP), including verification against observations, especially and mainly with regards to MLP.

IMGW-PIB operates a post-processing system based on the EPS system and the use of an artificial neural network ANN.

Operational setup of ANN at IMGW-PIB

- EPS-ANN: 25 input neurons (20 members + λ,φ,h,ts); 5 neurons in a single hidden layer (four blocks of TL-ICs/BCs and spatio-temporal coordinates – blocked)
- det-ANN: 12 input neurons (8 members for 36 hours + λ,φ,h,ts); 2 neurons in a single hidden layer (referring to a single block of det-DMOs and spatio-temporal coordinates – blocked)
- Every forecast (temperature, wind speed, pressure, etc.) treated independently
- Activation function: hyperbolic tangent (symmetric with respect to 0,0)
- Training method: backward propagation of errors (back-prop)
- Optimization: gradient descent.

EPS-based ANN and deterministic (time-lagged) ANN

Means	**ME**	**MAE**	**RMSE**	**MinE**	**MaxE**
Dew point					
DMO	0.299	**2.618**	**4.021**	-	-
det-ANN	**-0.412**	2.214	3.618	-16.2	17.1
EPS-ANN	**-0.271**	**2.101**	**3.263**	**-14.1**	**16.9**
Air temp.					
DMO	**0.953**	**2.953**	**4.619**	-	-
det-ANN	0.651	2.740	3.921	-17.1	19.1
EPS-ANN	**0.219**	**2.603**	**3.682**	**-15.2**	**17.8**
Wind speed					
DMO	**-0.837**	**2.023**	**3.150**	-	-
det-ANN	**0.351**	1.759	2.719	-9.4	16.0
EPS-ANN	-0.425	**1.572**	**2.236**	**-8.8**	**14.1**

Comparison of the results
(observations vs. forecasts,
2011-present, ongoing)

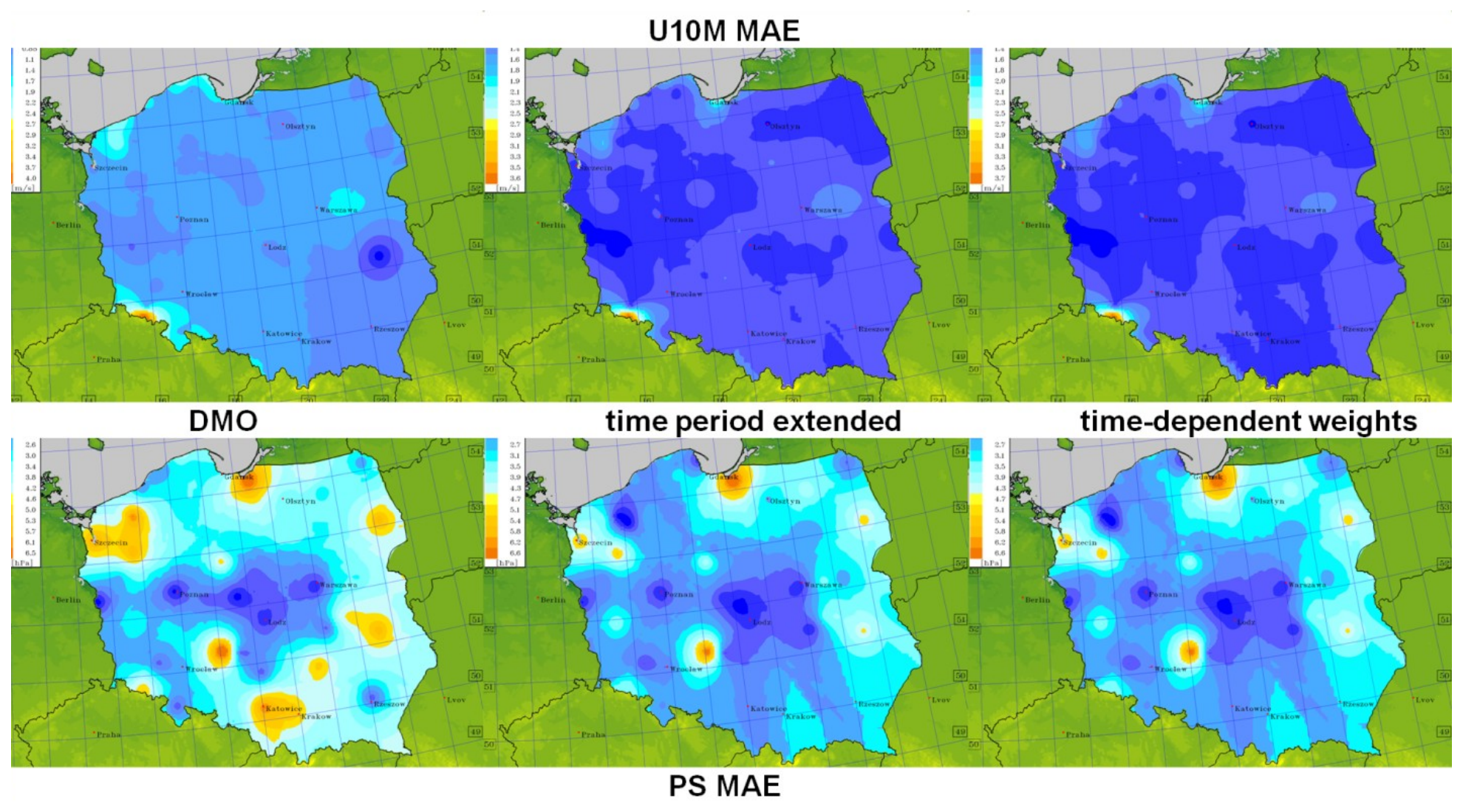
EPS-based ANN produces more precise results. It might be connected with the greater number of members, which, on the other hand, translates into longer learning and testing time for the network.

Weighted Multi-Linear Regression (WMLR) - test phase

Comparison of the results of WMLR

procedure with DMO (left),
weight changed via extension of learning time period
(2 months backwards; middle),
time-depended weights (linear dependency; right).

Testing / learning period – fall 2020-present.



The WMLR has not yet been tested on a longer dataset, therefore it is difficult to compare its results with those from EPS/det based ANN. The purpose of the WMLR application is to use it either during the transition period (e.g. from COSMO to ICON) from one setup to another, rather different qualitatively and/or quantitatively or when there are problems with the availability of appropriate computing resources (data volume, computing performance).

Very-high resolution NWP

Dependence of a representation of Alpine convective currents on vertical resolution and topography smoothing with COSMO-EULAG

1. Introduction

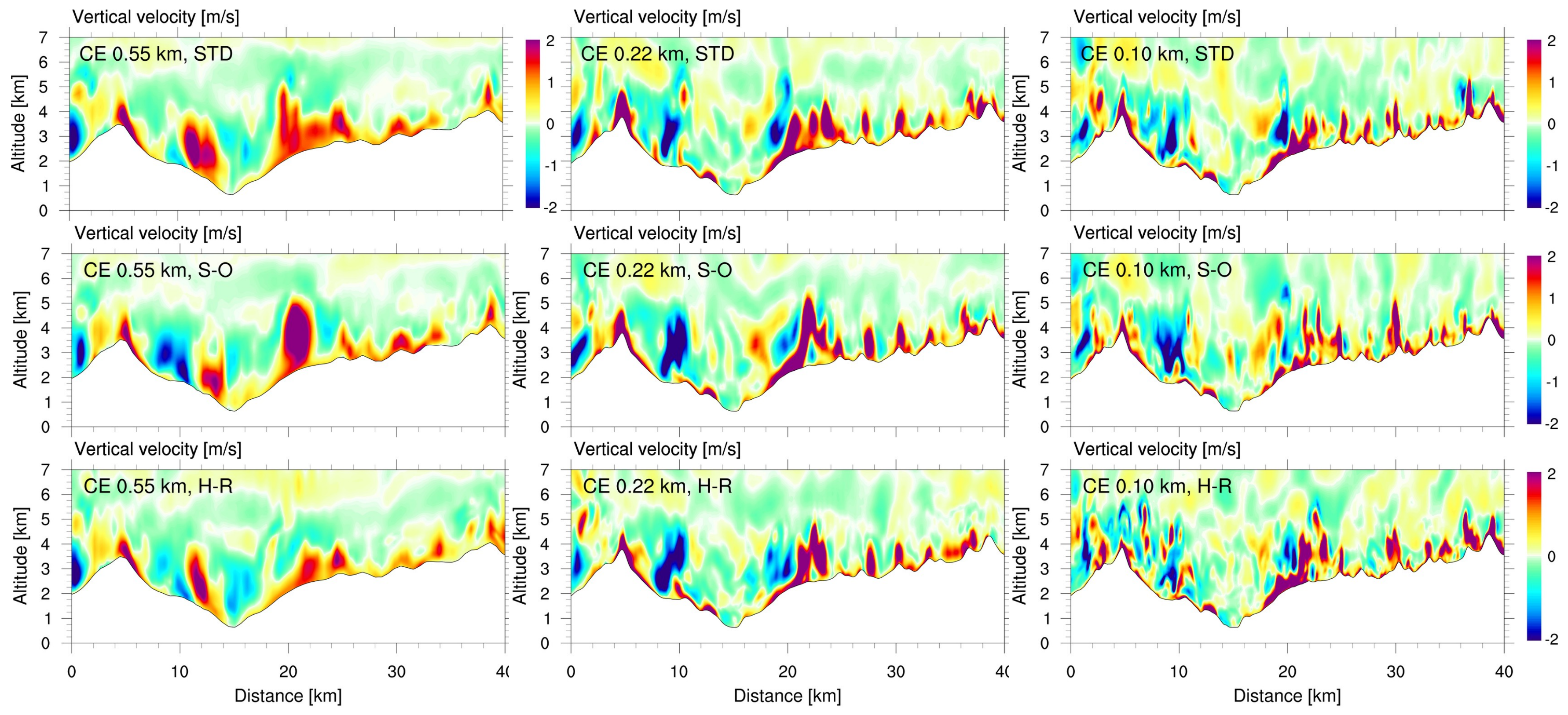
A new version of the COSMO model employing EULAG dynamical core (COSMO-EULAG: CE) was developed at IMGW-PIB for convection-permitting NWP applications (Ziemiański et al. 2021). The compressible semi-implicit non-hydrostatic dynamical core of EULAG is used (e.g. Smolarkiewicz et al. 2014). The core is 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 CE was tested for very-high resolution representations of the Alpine flow and compared with standard COSMO model employing Runge-Kutta dynamical core showing good verification results (Ziemiański et al. 2021). The COSMO-EULAG was tested for Alpine convection developing within weak flow regime on 19 July 2013. The model uses standard configuration of 60 vertical levels and provides realistic representation of cloud cover and convective currents using the horizontal grids of 2.2, 1.1, 0.55, 0.22, and 0.1 km. The model demonstrates its numerical robustness for Alpine slopes reaching up to 85 degrees.

3. Representation of convective currents and model configuration

The same case-study is used to analyze the dependence of a representation of Alpine convective currents on model vertical resolution and representation of topography. The latter is filtered to eliminate spurious 2 delta x oscillations and the minimum length scale of the standard filter (where its response function is 0.5) is 4.3 delta x. Here, an experimental forecast is performed with steeper orography filtered using a similar filter having the minimum length scale of 3.1 delta x. Further experimental forecast is performed for the standard orography filtering but with vertical resolution increased to 84 vertical levels, following the operational configuration of the MeteoSwiss. The experiments are performed for horizontal grids of 0.55, 0.22 and 0.1 km and they employ the 3-dimensional Smagorinsky turbulence scheme (Baldauf and Brdar 2016).



The figure shows the vertical cross section through the vertical velocity over the Rhone Valley between Bietschhorn (left) and Weisshorn (right), for the standard model configuration (STD, top), steeper orography (S-O, middle row), and enhanced vertical resolution (H-R, bottom), for horizontal grid sizes of 0.55 (left), 0.22 (middle), and 0.10 km (left) on 19 July 2013, 1300 UTC.

The model vertical velocity crucially depends on the horizontal resolution of the model. However, also the vertical resolution and the level of orography filtering strongly influence the pattern and structure of the vertical velocity fields as well as amplitudes of its perturbations, the latter especially at 0.55 km grid.

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. 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.
3. Ziemiański, M.Z., D.K. Wójcik, B. Rosa, Z.P. Piotrowski, 2021, Compressible EULAG dynamical core in COSMO: convective scale Alpine weather forecasts, Mon. Wea. Rev., accepted for publication August 2021

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