Numerical Weather Prediction at IMGW-PIB

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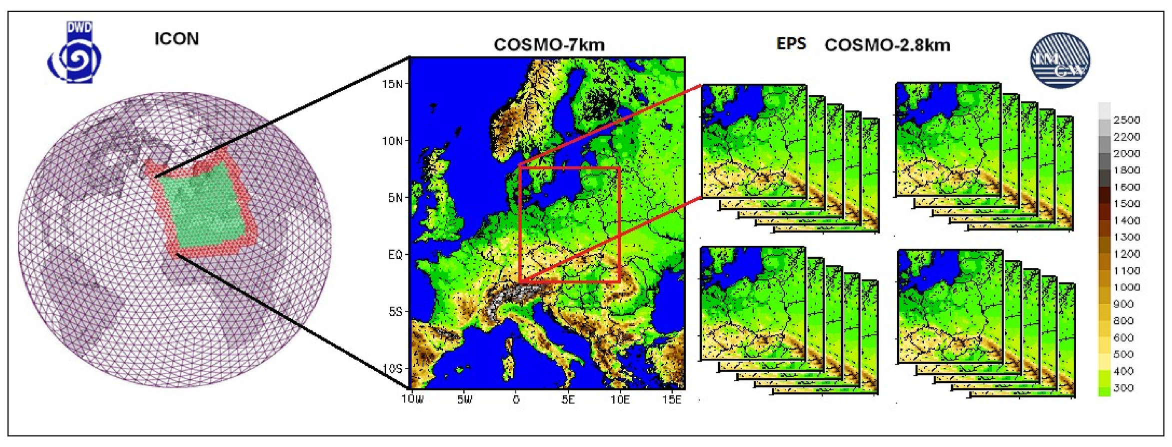
Status of the operational suite & Computing system

Operational – COSMO

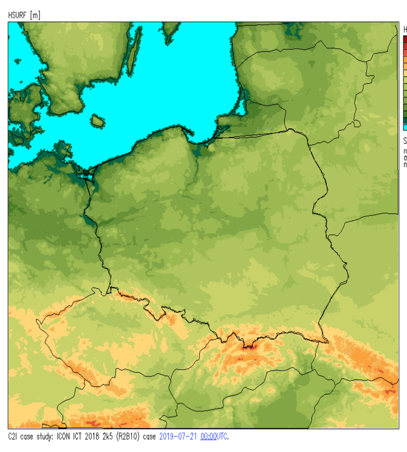


Horizontal Grid Spacing [km]	7	2.8	2.8 EPS
Domain Size [grid points]	415 x 445	380 x 405	
Vertical levels	40	50	
Time Step [sec]	40	20	
Forecast Range [h]	82	48	
Initial Time of Model Runs [UTC]	00 06 12 18		
Data Assimilation Scheme	Nudging		
Model Version Run	5.01		
Model providing LBC data	ICON	COSMO PL 7	
LBC update interval [h]	3h	1h	

LINUX CLUSTER „Grad"

- 4 casette systems c7000
- 145 servers BL460c Gen8
- 128GB RAM6 management nodes,
- 2 x 8-Core CPU139 computation nodes,
- 2 x 10-Core CPU performance - HPLinpack test ~61TFlops
- disk array HP3PARStoreServ7400 ~70TB capacity

Semi Operational – ICON PL



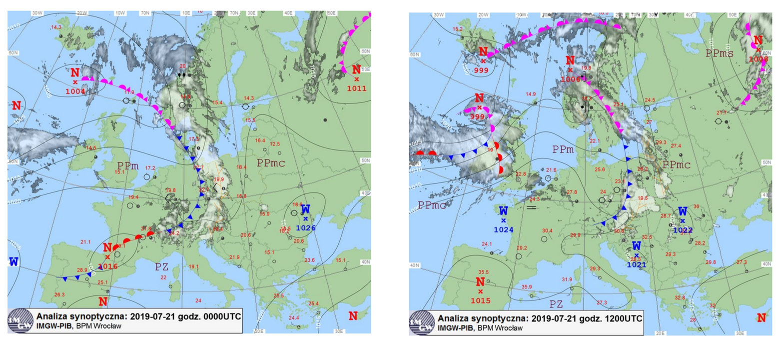
ICON PL setup

- 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 UTC
- No data assimilation scheme
- LBC data provided from ICON
- 3h LBC Update interval

Comparison between ICON PL and COSMO PL 2.8 km – preliminary results

The COSMO consortium science plan calls for a harmonization of development of the COSMO-model and ICON. A migration (smooth transition) to ICON-LAM (ICOsahedral Nonhydrostatic - Limited Area Mode) as the future operational model is a main goal of priority project C2I (COSMO to ICON). ICON PL has run semi-operational at IMGW-PIB since June 2019.

Case study: 21st July 2019

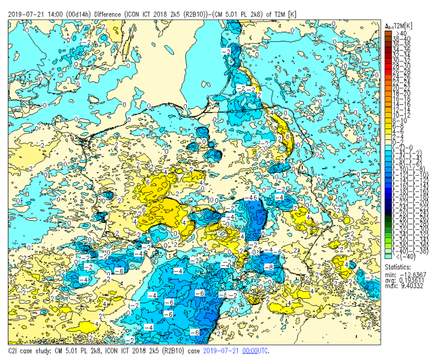


Synoptic situation

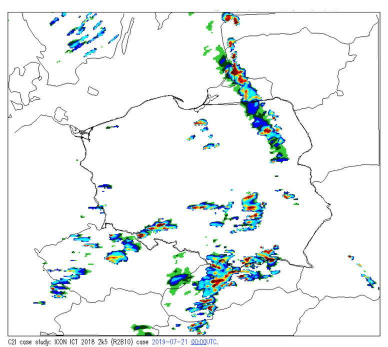
On 21st of July Poland was mostly under the influence of low pressure systems, moving from west to east with atmospheric fronts. Polar maritime air mas was coming in, usually quite cool, only temporarily warmer. Broken clouds, with rain showers and thunderstorms, were accompanied in some places by heavy or torrential rain and hailstorms.

Temperature at 2m, 14.00 UTC | **Accumulated precipitation 1h, 14.00 UTC**

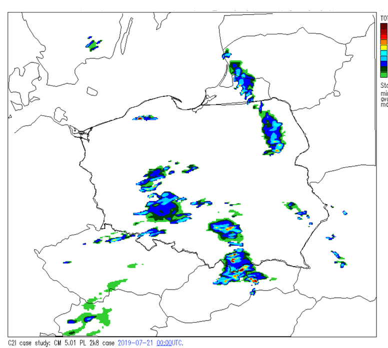
Difference ICON PL - COSMO PL



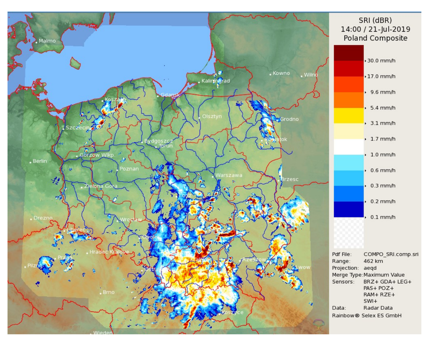
ICON PL



COSMO PL



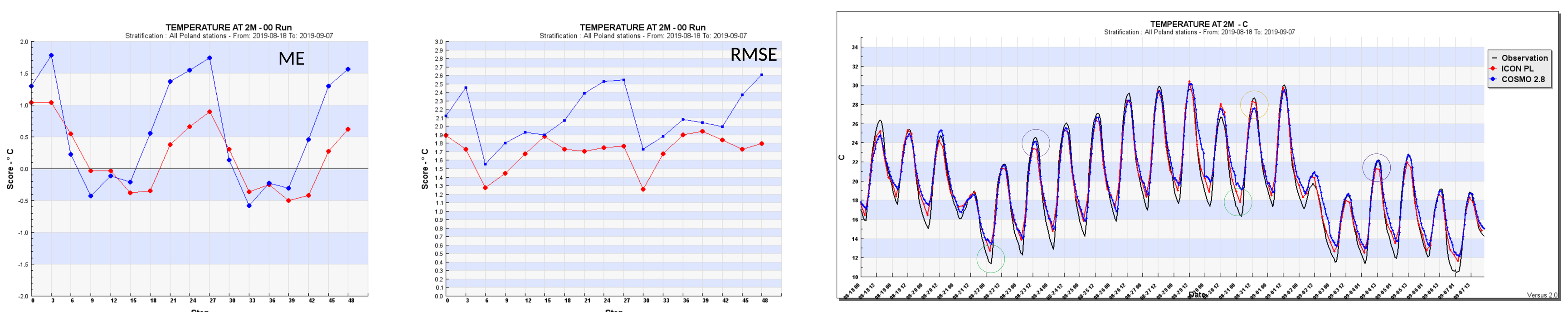
Radar



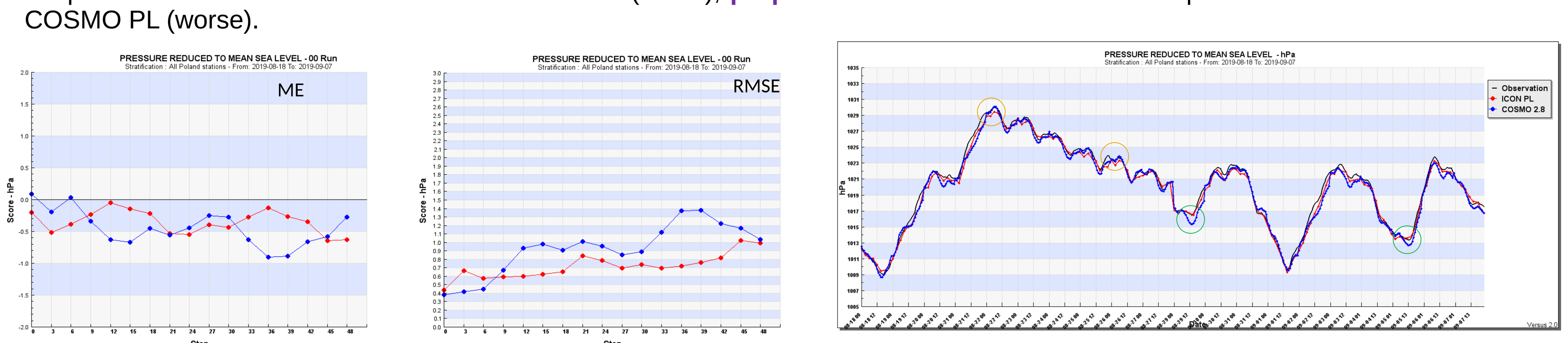
2 m temperatures forecasted by ICON PL are at least 1°C lower than temperatures forecasted by COSMO PL. 2m temperature fields have different structures due to differences in precipitation fields. The rainfall area on the northeastern part of Poland is predicted by the both models but it seems to be slightly shifted westerly and overpredicted compared with observations. COSMO PL predicted the occurrence of rain in the Lower Silesia where it actually did not appear. In turn, ICON PL underestimated the intensity of the precipitation over Malopolska region (southern part of Poland).

Case study: 18th August – 07th September 2019

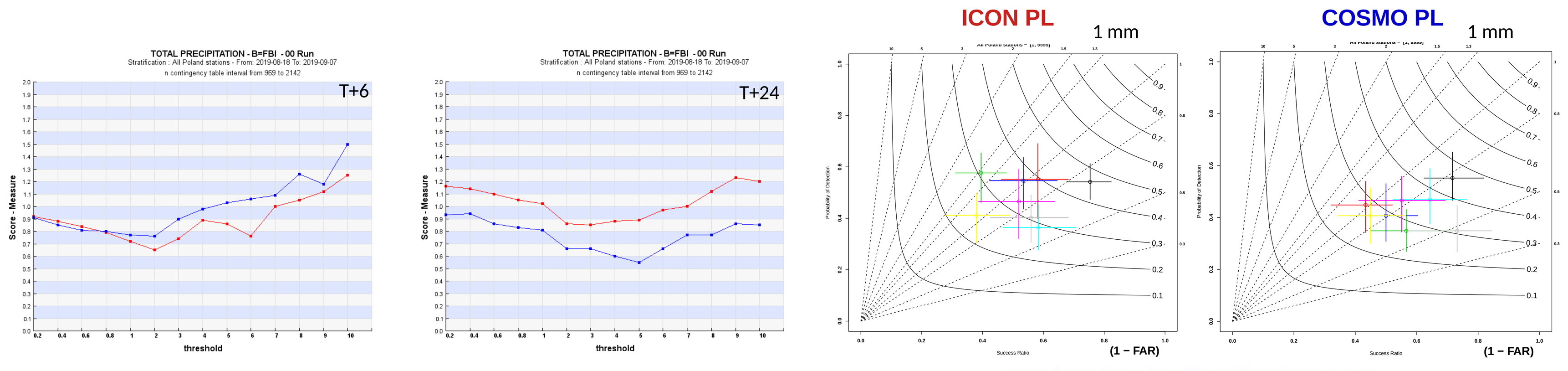
Verification results of **ICON PL** and **COSMO PL 2k8** compared with **SYNOP** are shown below.



Temperature at 2 m:
ICON PL - better BIAS and RMSE than COSMO PL, ICON PL colder than COSMO PL. Diurnal cycle of temperature in both models is damped compared to the observations. Diurnal range of temperature in ICON PL is sometimes greater than COSMO PL (closer to the observations). **Green circle** shows the night time temperature colder than COSMO PL (better). **Orange circle** – ICON PL maximum temperature is sometimes warmer than COSMO PL (better), **purple circle** - ICON PL maximum temperature is sometimes colder than COSMO PL (worse).



Mean Sea Level Pressure:
ICON PL - no gross errors apparent, generally better bias and RMSE than COSMO PL. **Green circle** - ICON PL better than COSMO PL (closer to the observations), **orange circle** - ICON PL worse than COSMO PL (further away from the observations).



Total precipitation 6h:
At short forecast range (T+6) and low thresholds both models underestimate precipitation. Underestimation by ICON PL seems to be greater for the precipitation amount between 1 and 3 mm. Rainfall amount between 4 and 6 mm is overestimated by COSMO PL but underestimated by ICON PL.
At forecast range T+24 COSMO PL underestimates rainfall amount for the all thresholds. ICON PL overestimates low and high precipitation while underestimates precipitation between 2 to 5 mm.

The verification results can be only regarded as preliminary. The longer period of data is needed to make a more statistically robust comparison between both models.

References:
1. Priority Project "C2I" Transition of COSMO to ICON-LAM – project plan
2. Roebber, P.J., 2009: Visualizing multiple measures of forecast quality. Wea. Forecasting, 24, 601-608

Research & Development

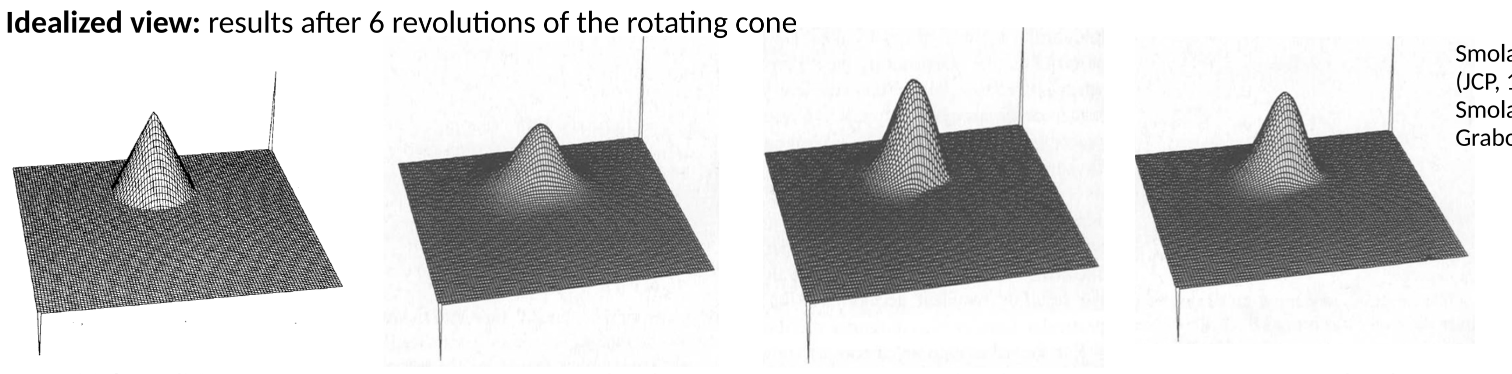
Operationalisation of COSMO-EULAG

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 core employs multidimensional positive definite advection transport algorithm (MPDATA) and there is no explicit numerical diffusion. The EULAG dynamical core is linked with physical parameterizations and infrastructure of the COSMO model version 5.05. The model was thoroughly tested, e.g. over Alpine domain of MeteoSwiss. Since June 2018 the model routinely provides a numerical weather forecast for Poland.

2. Selection of the MPDATA advection variant

Idealized view: results after 6 revolutions of the rotating cone



Smolarkiewicz and Clark (JCP, 1986)
Smolarkiewicz and Grabowski (JCP, 1990)

Initial condition | MPDATA-A 2nd order | MPDATA-M 2nd order | MPDATA-A 3rd order

- The MPDATA-A is more diffusive and less accurate
- The MPDATA-M is less diffusive and more accurate
- In the corrective flux calculation for MPDATA-M it is assumed that the advected field has a large background constant
- Both may be applied for advection of dynamical and moist variables and TKE

Operational view: verification of weather forecasts

- The simulations are performed for two CE setups employing either MPDATA-A or MPDATA-M scheme for solving the advection equation

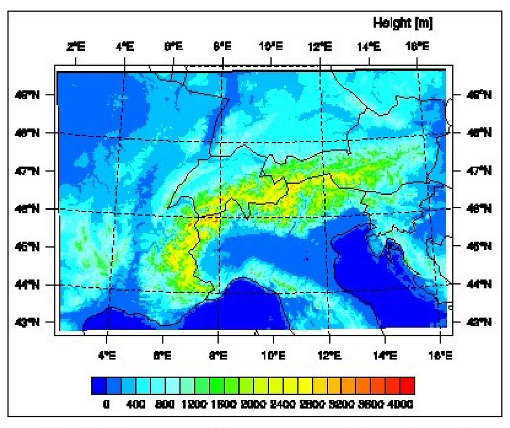


Fig 1. Topographical map of the domain

- Forecasts computed for the whole month July 2013 and compared with observations using dedicated official COSMO verification software VERSUS (surface stations shown on right)
- Realistic simulations were performed for each day separately (48h forecast)
- Horizontal step of the computational mesh is 2.2 km
- Domain corresponds to the standard operational COSMO-2 domain of Meteo-Swiss (2013, left)

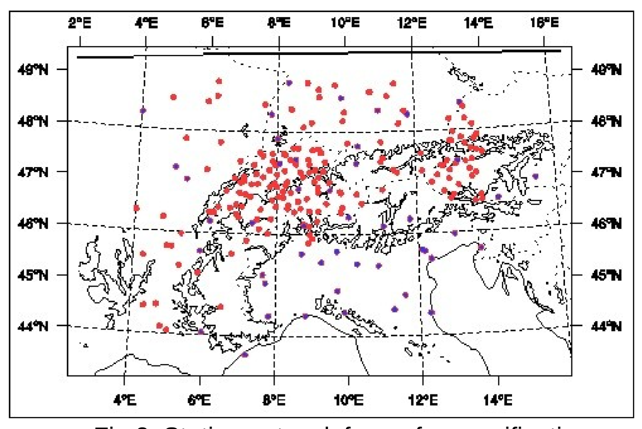
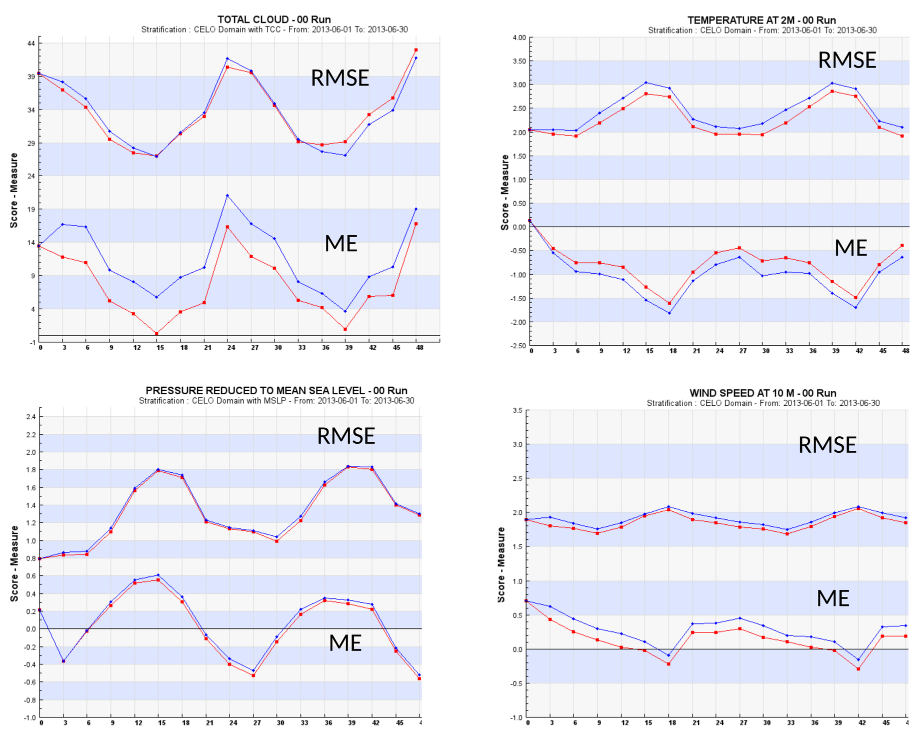
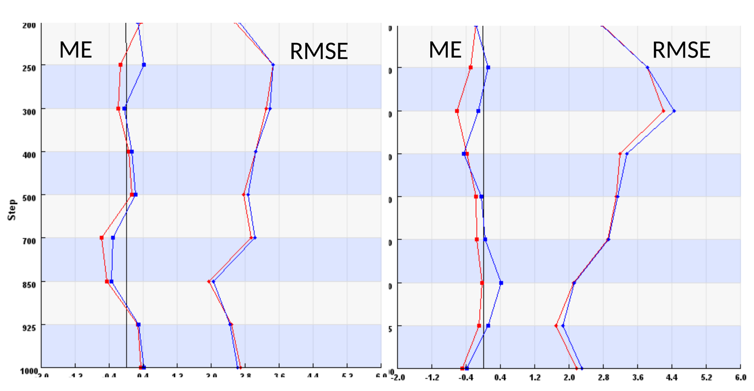


Fig 2. Station network for surface verification



Upper-air wind speed



Conclusions:
COSMO-EULAG with the more diffusive MPDATA-A scheme provides forecasts having slightly better verification scores.

3. Verification of the semi-operational COSMO-EULAG forecasts for the COSMO-2k8-PL domain

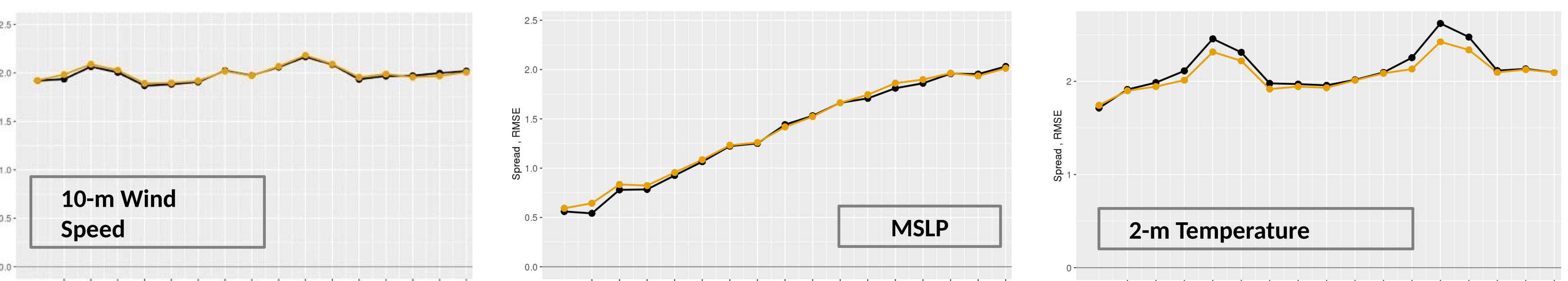
Model setup:

- Standard orography filtering is applied
- Turbulence (*itype_turb=3*), microphysics (with cloud ice), soil model and radiation (with coefs. updated every 7.5 minutes) are turned on
- For COSMO Runge-Kutta (C R-K) *irunge_kutta=1* and *itype_fast_waves*=2
- For COSMO Runge-Kutta (C R-K) the numerical filtering is *turned on*
- The set of weather station used for verification is different from the set of stations utilized for nudging
- For C-E *dt* = 12 s, for RK *dt* = 20 s

Experiment setup:

- COSMO-PL 2k8 domain with 380 x 405 x 50 grid points
- Forecast time 48 h, with 4 h nudging window
- Verified with SYNOP (60 stations)

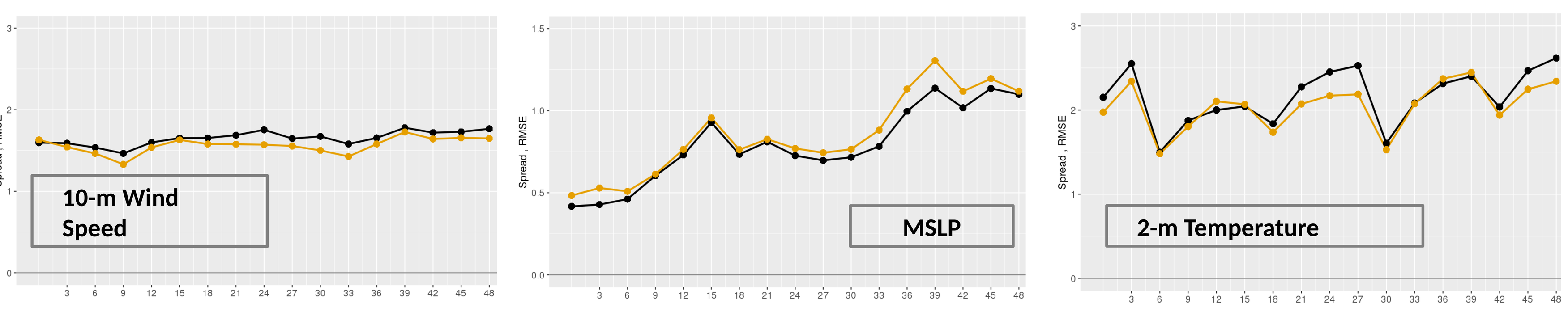
15 January till 14 February 2019, 0:00 UTC forecasts, RMSE



The RMSE scores for this winter period are very similar

COSMO R-K (ver. 5.01)
COSMO-EULAG (ver. 5.05)

25 July till 24 August 2019, 0:00 UTC forecasts, RMSE



- For 10-m wind speed and 2-m temperature the RMSE is slightly lower for C-E
- For MSLP the RMSE is slightly lower for C R-K

4. Summary

The COSMO-EULAG model was successfully developed at IMGW-PIB and provides a routine numerical forecast for Poland with verification scores competitive with the scores of the default COSMO model employing Runge-Kutta dynamical core.

References:
1. 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.
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. 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 flows. J. Comput. Phys. 314, pp. 287-304.

41st EWGLAM and 26th SRNWP Meeting, 30th September- 03th October 2019, Sofia, Bulgaria