Final report on PP CELO

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Overview of project tasks

Task 1: Integration of EULAG DC with COSMO framework

•The EULAG compressible dynamical core has been successfully coupled to the COSMO framework ver. 5.04h. *The new code is called further on as CI*.
•EULAG dy-core is linked with ICON physics parameterizations of COSMO ver. 5.04h.

•The task aimed at investigation and implementation of the strategy regarding lowest level of EULAG dynamical core on the surface is carried out within COSMO Priority Project EX-CELO (In current implementation there is no additional surface layer).

Task 2: Consolidation and optimization of the EULAG DC formulation

•Optimization of boundary conditions (velocity bc's for MPDATA) have been performed.
•The compressible dynamical core does not require a special treatment of variable mass in the computational domain nor implementation of time-dependent coordinate.

Task 3: Eulag DC code restructuring and engineering

•Implementation of a basic restart subroutine in the CI is almost completed. Testing with the Standard Test Suite revealed some differences when no-zero precipitations at the domain's lateral boundaries. The problem has been diagnosed and finalization of the restart procedure is planned, soon.

Overview of project tasks

Task 4: Optimization and testing of COSMO with EULAG DC

•Optimized integrated code for operational COSMO model with EULAG DC (with no assimilation implemented) has been developed.
•Number of realistic simulations have been performed. In most considered cases the forecasts computed using COSMO model with EULAG DC are closer to observations than analogous with RK DC (statistical verifications).
•The draft scientific documentation of the code is prepared.

Task 5: Integration and consolidation of the EULAG compressible DC with COSMO framework

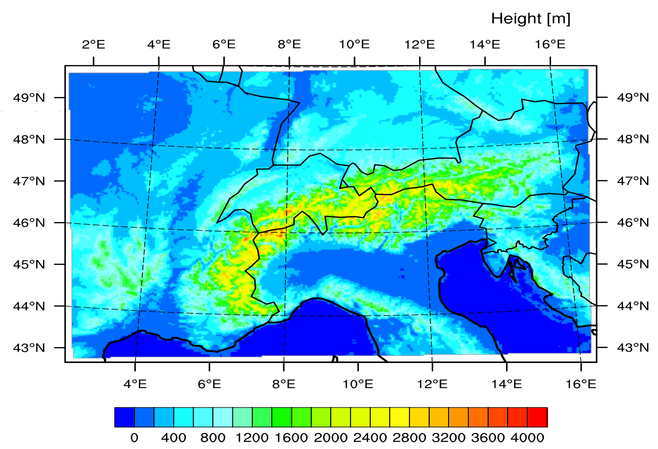
•Problem with the pressure bias has been solved by applying lateral absorbers.
•The compressible EULAG DC is available for implementation into official COSMO model.

•Single precision EULAG DC – this task is currently carried out within COSMO priority project EX-CELO.

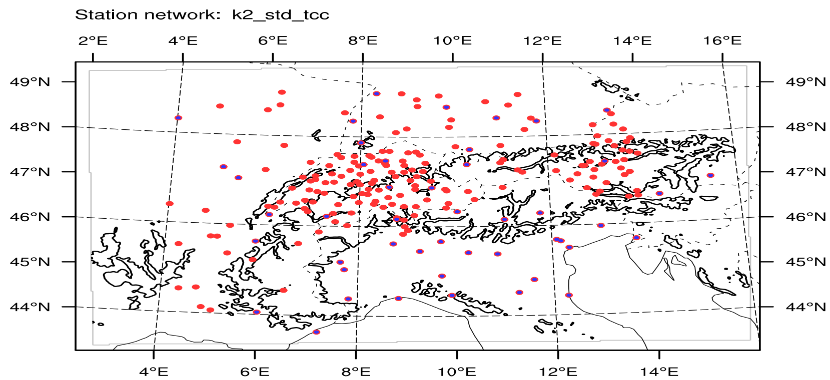
Verification of CI forecasts computed for JUL 2013 (**48h forecast**)

- The CI numerical forecasts were computed for the whole month July 2013 and compared with observations using dedicated application Versus.
- 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.
- The simulations were performed using both CI and RK – for comparison

Topographical map of the domain



Station network for surface verification



Experiment settings

Dynamics:

- In Cosmo Runge-Kutta setup moist quantities are advected using the „Bott2Strang" scheme
- In Cosmo-Eulag setup moist quantities are advected using the MPDATA A scheme
- For Cosmo Runge-Kutta *irunge_kutta=1* and *itype_fast_waves=2*
- dt = 10 s (RK), dt = 10 s (CI)
- Numerical and Smagorinsky diffusion are *turned off* for Cosmo-Eulag and *on* for Cosmo Runge-Kutta

Microphysics:

- Standard one-moment COSMO microphysics parameterization including ice, rain, snow and graupel precipitation (*igsp=4*)

Radiation:

- Calculated every 6 minutes
- Topographical corrections to radiation are turned off (*lradtopo=F*)

Turbulence and convection scheme:

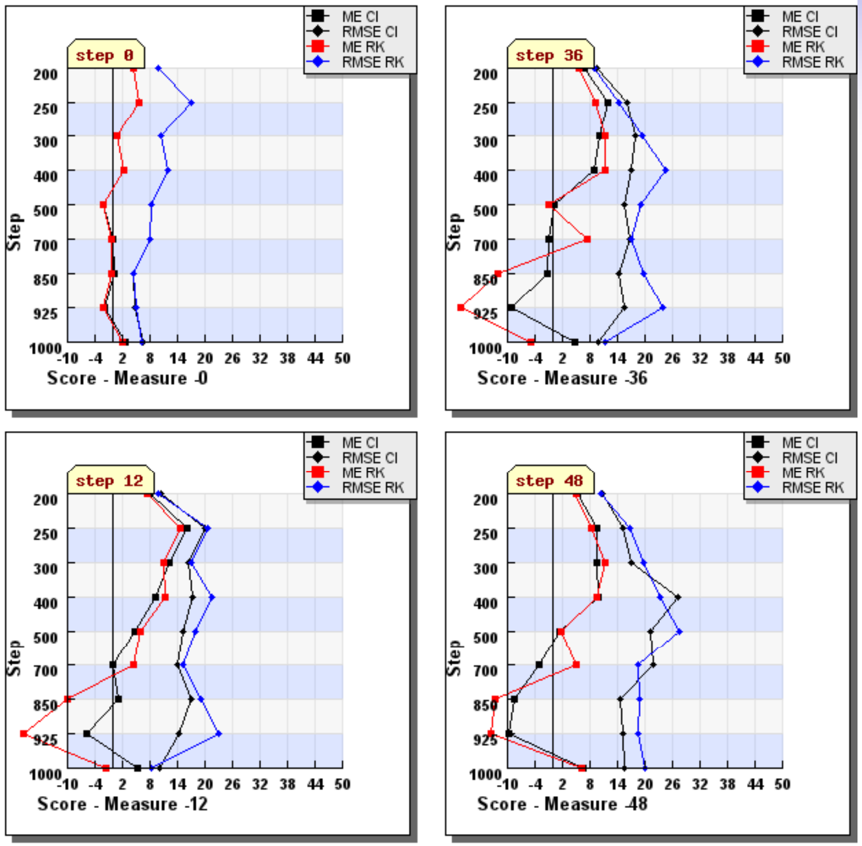
- Default turbulence setup for high-resolution NWP (*itype_turb=3, limpltkediff=T)*
- Shallow convection parameterization is turned off (*lconv=F)*

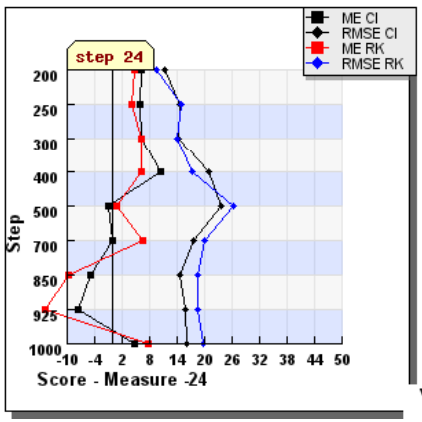
Soil model:

- Multi-layer soil model is used (*lsoil= T, lmulti_layer=T,* lforest=T)

Relative humidity - Cross validation - start at 0:00 UTC

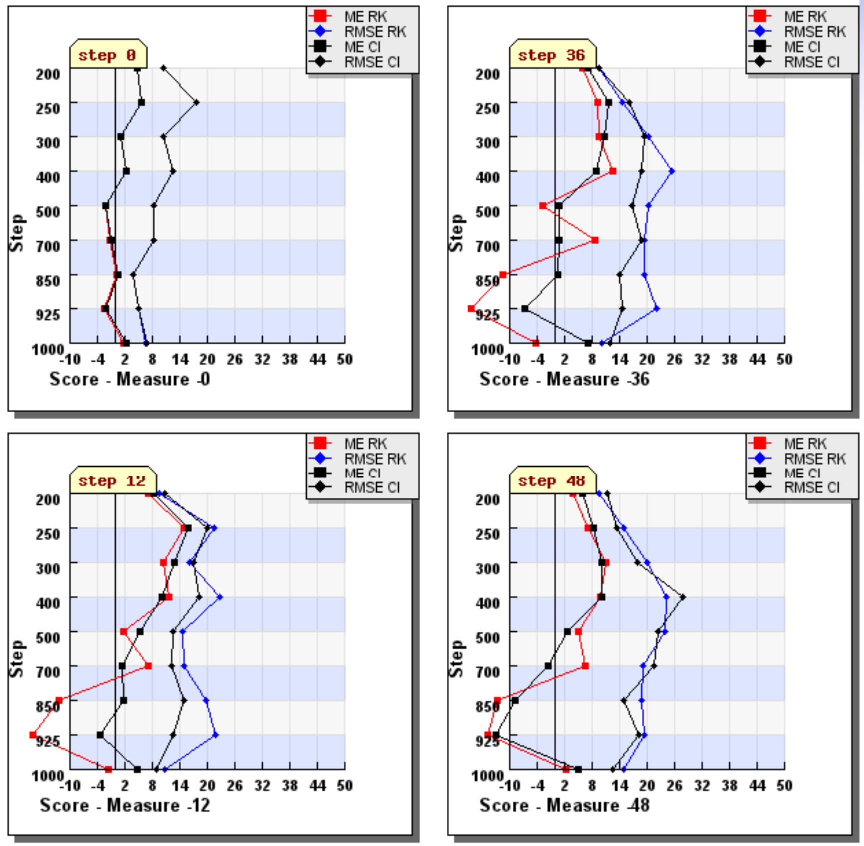
Default settings

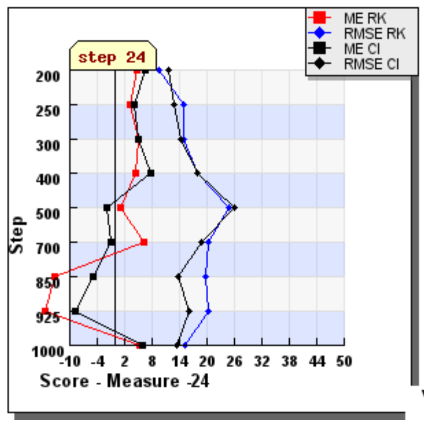




Versus 2.0

CALMO optimization



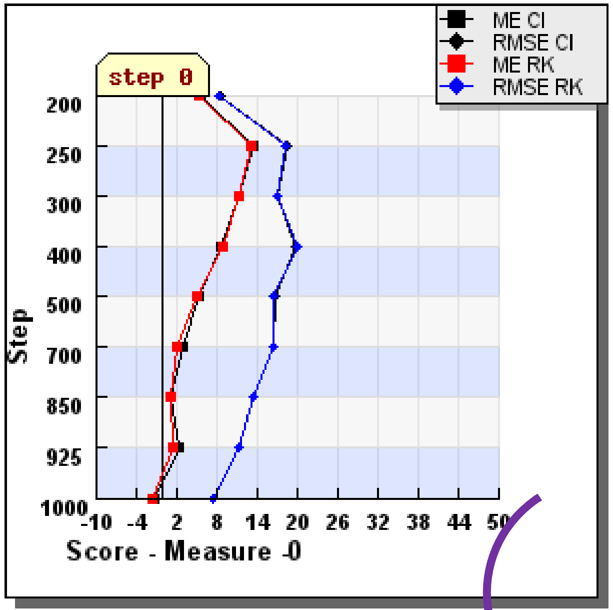


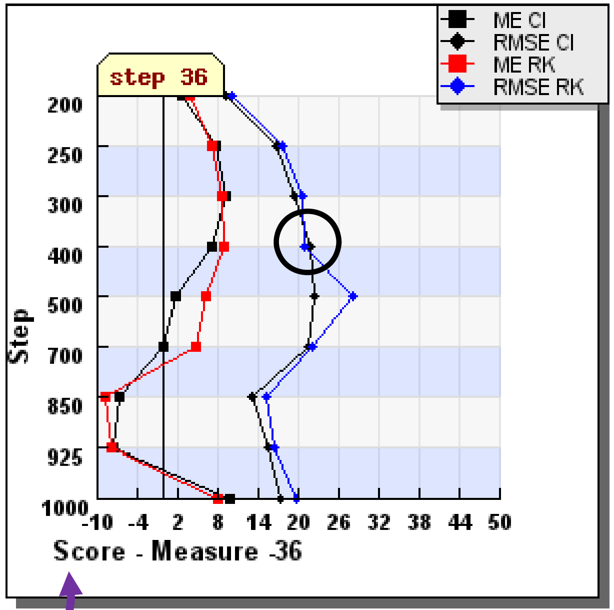
Versus 2.0

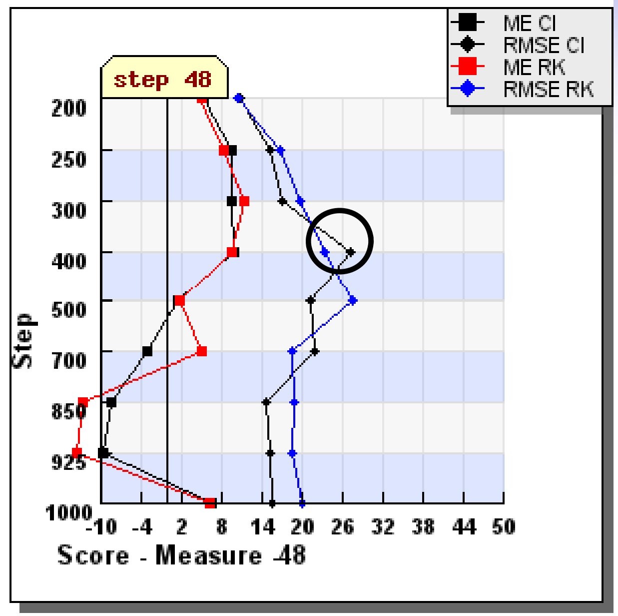
1. In most considered cases, the numerical forecast computed using CI is closer to observations than forecast computed with RK
2. Below the altitude corresponding to 250hPa and in particular close to the ground, ME and RMSE are significantly smaller in CI forecast
3. CALMO tuning has little effect on the average statistics

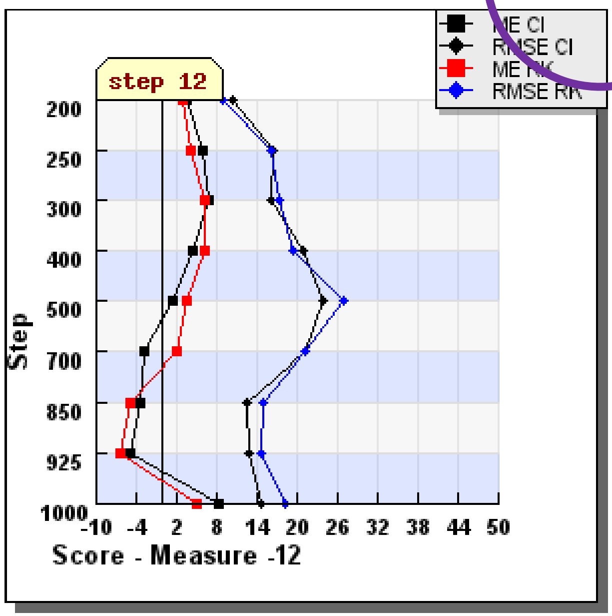
Relative humidity - start at 12:00 UTC

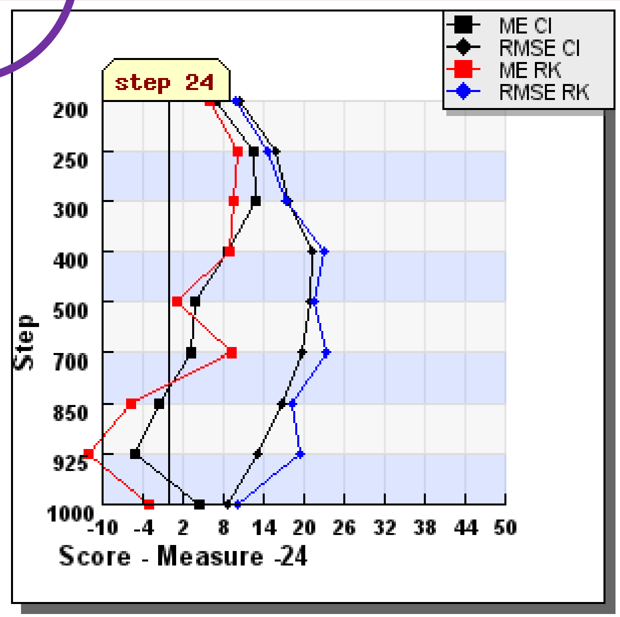
Default settings – start at 12:00 | **Start at 0:00**









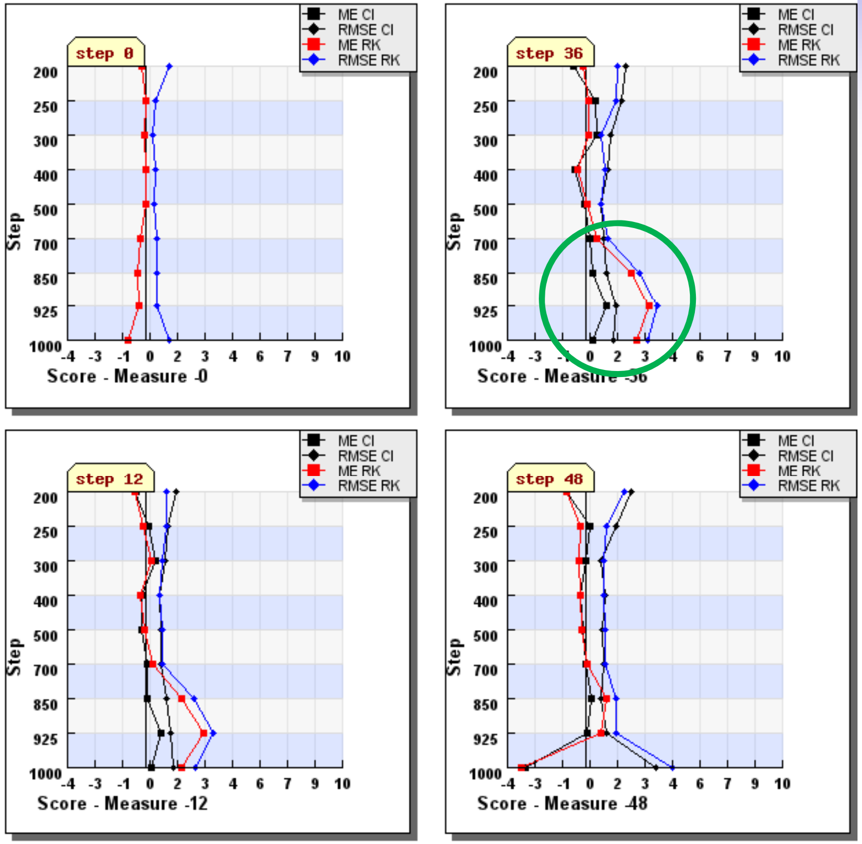


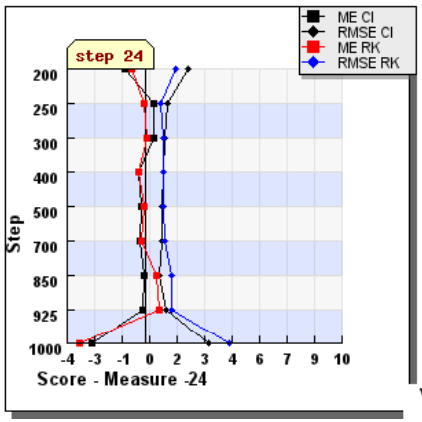
1. Later start results in further reduction of RMSE in CI simulations.
2. Consistently to previous results, CI forecast is closer to observations than RK.
3. There are larger oscillations in RK profiles.

4. At the top of the computational domain simulations performed using RK are in slightly better agreement with observations than CI.

Temperature - start at 0:00 UTC

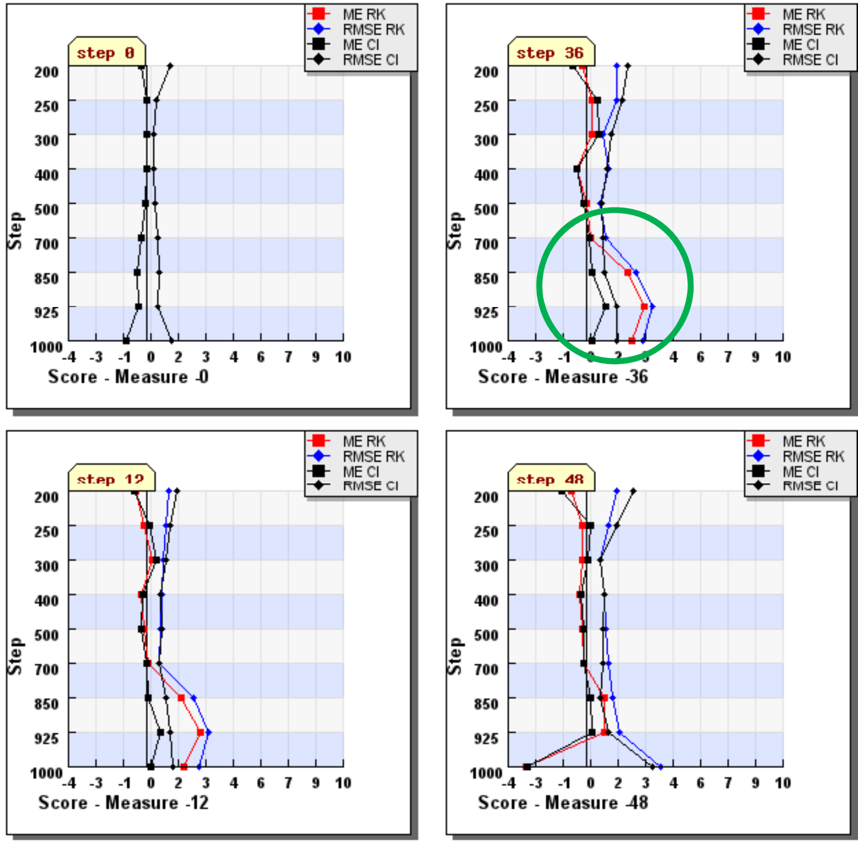
Default settings

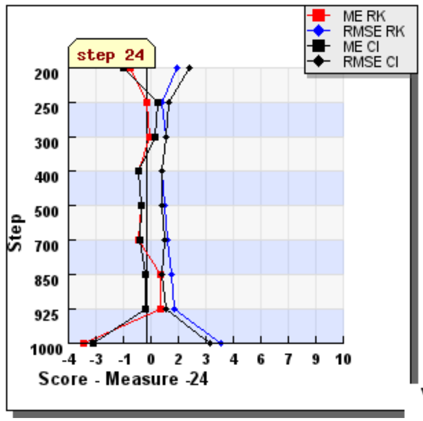




1. Analogously to previous results CI forecasts are closer to observations than RK
2. At midnight there is large difference between numerical forecasts (close to the ground) and observations. This may be due to less intense surface heat fluxes and cooling of the soil.
3. There is large difference between CI and RK after 12 and 36 hours. RK forecast significantly overestimates the measured data

CALMO optimization

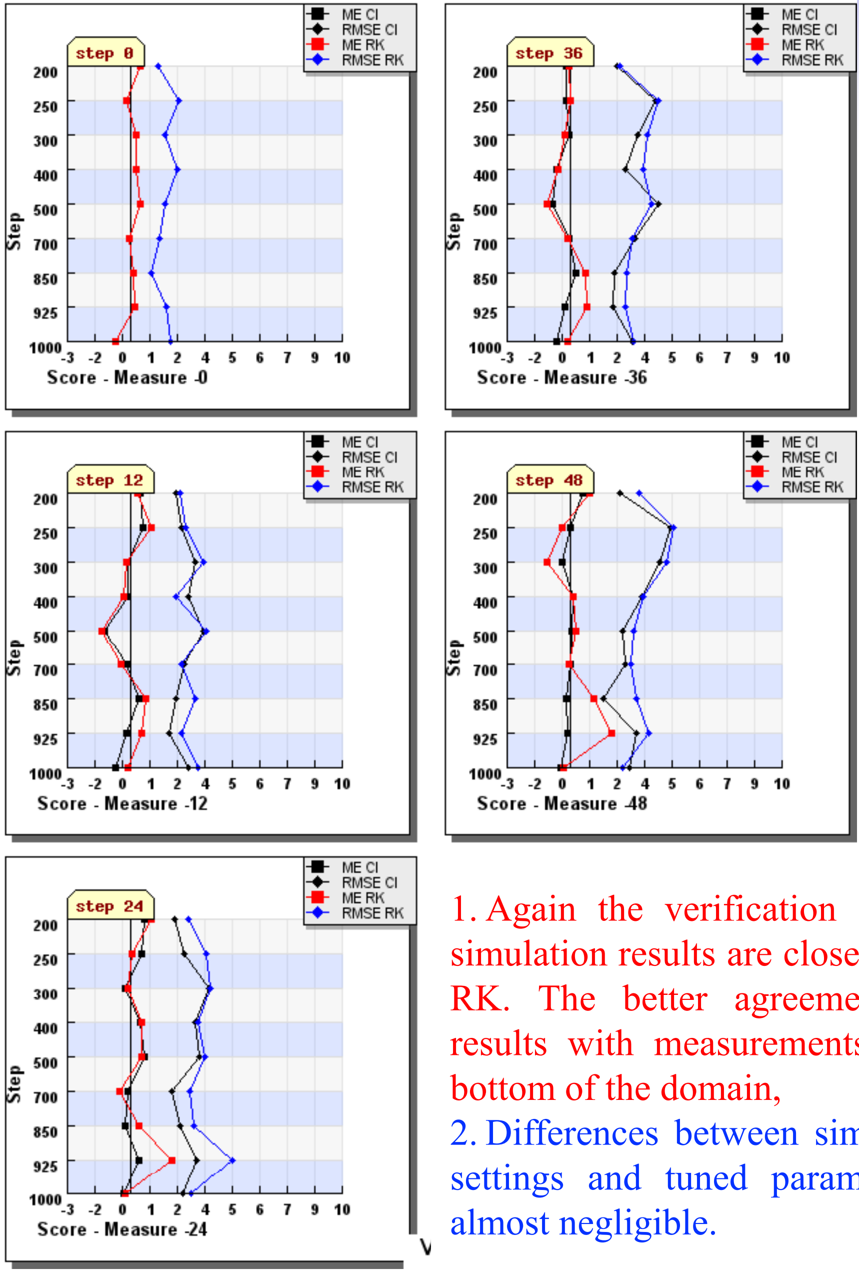




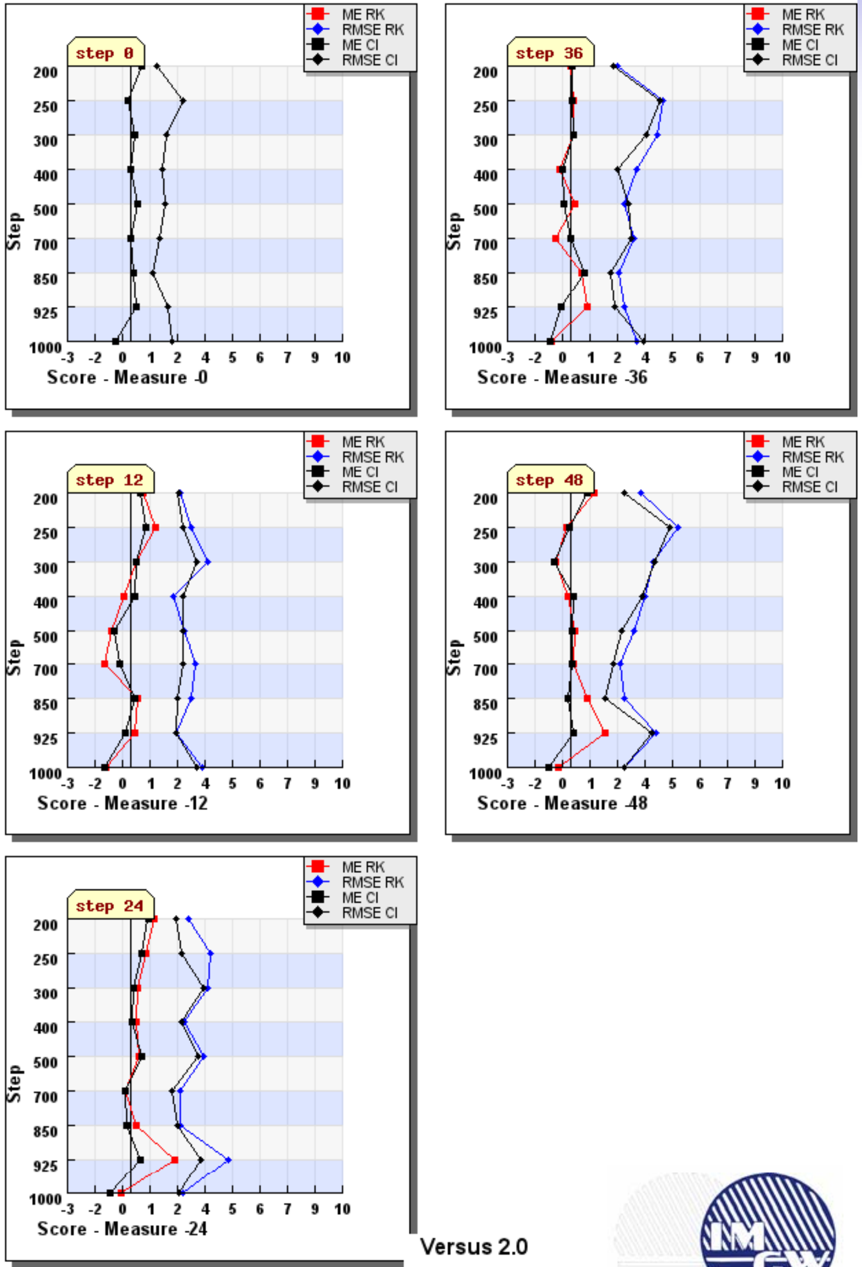
Versus 2.0

Horizontal wind [m/s] - start at 0:00

Default settings

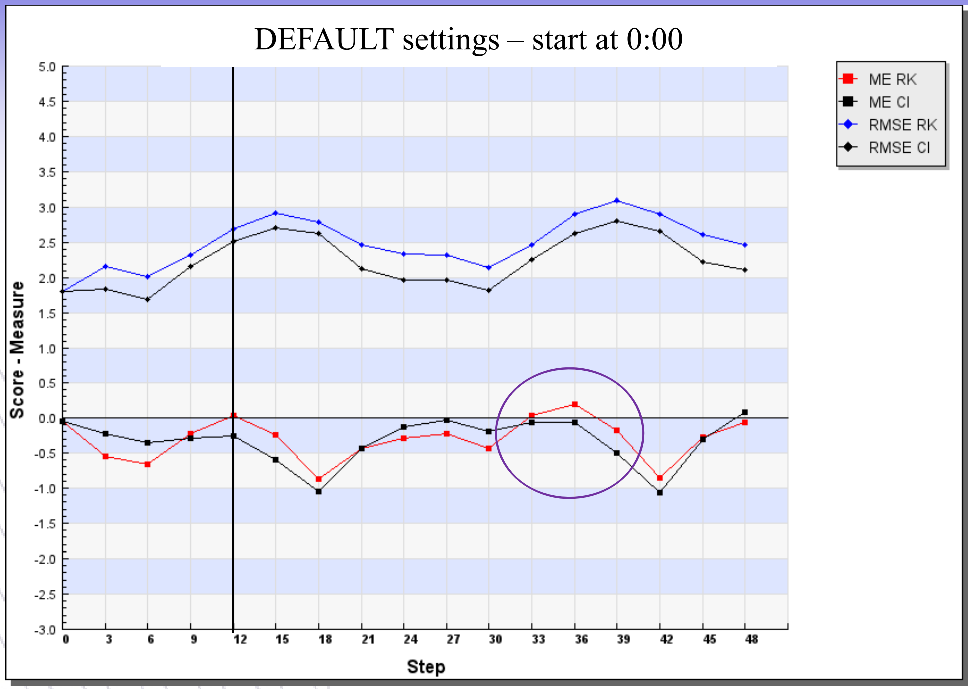


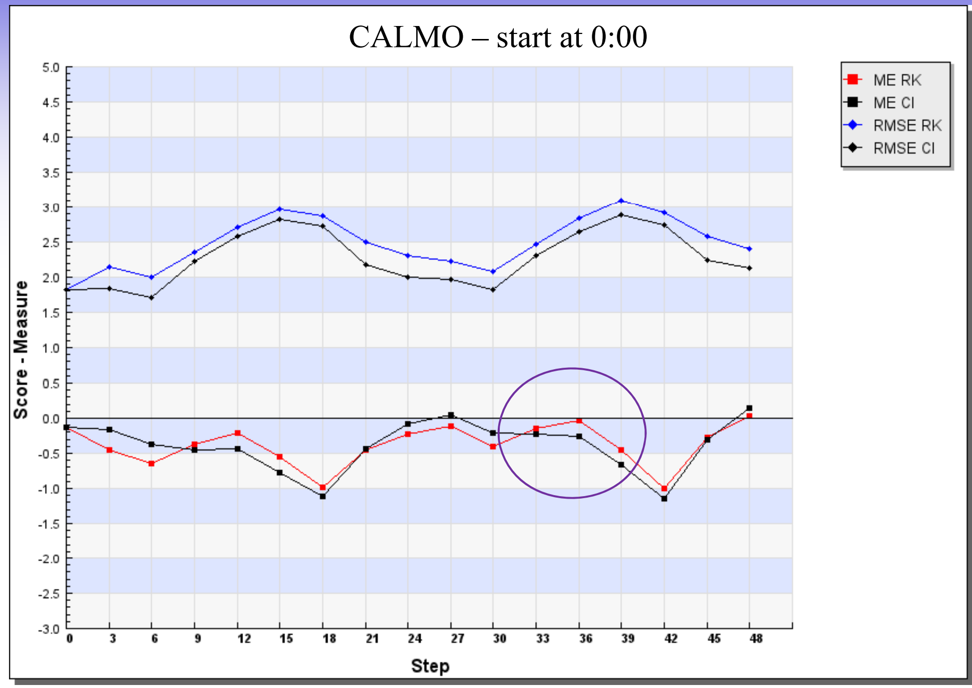
CALMO optimization

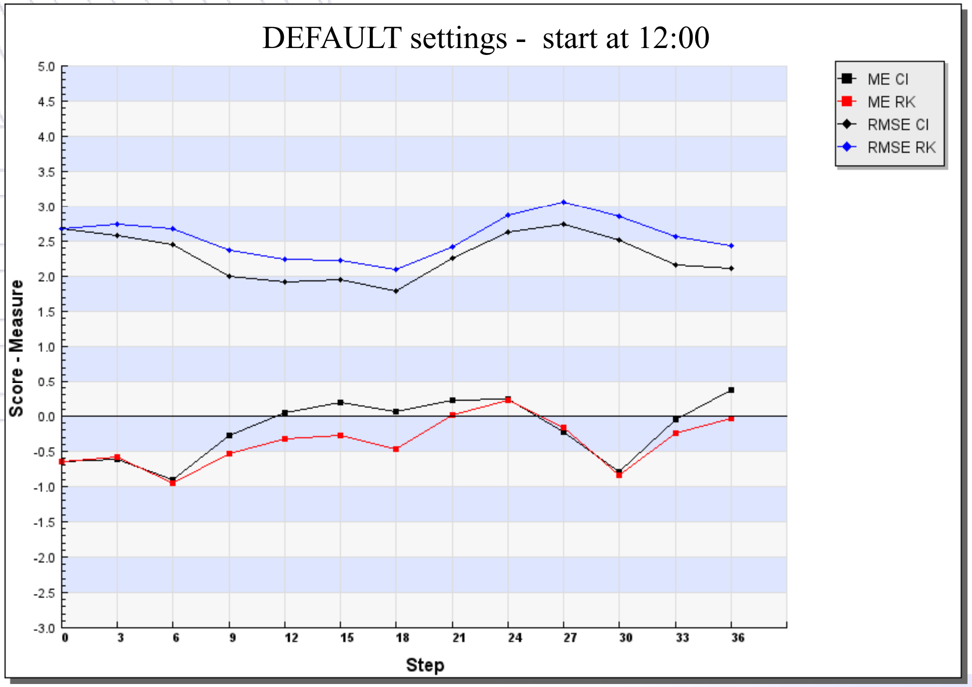


1. Again the verification scores show that CI simulation results are closer to observations than RK. The better agreement of CI numerical results with measurements is at both top and bottom of the domain,
2. Differences between simulations with default settings and tuned parameters (CALMO) are almost negligible.

Temperature [C] at 2 [m] – surface verification





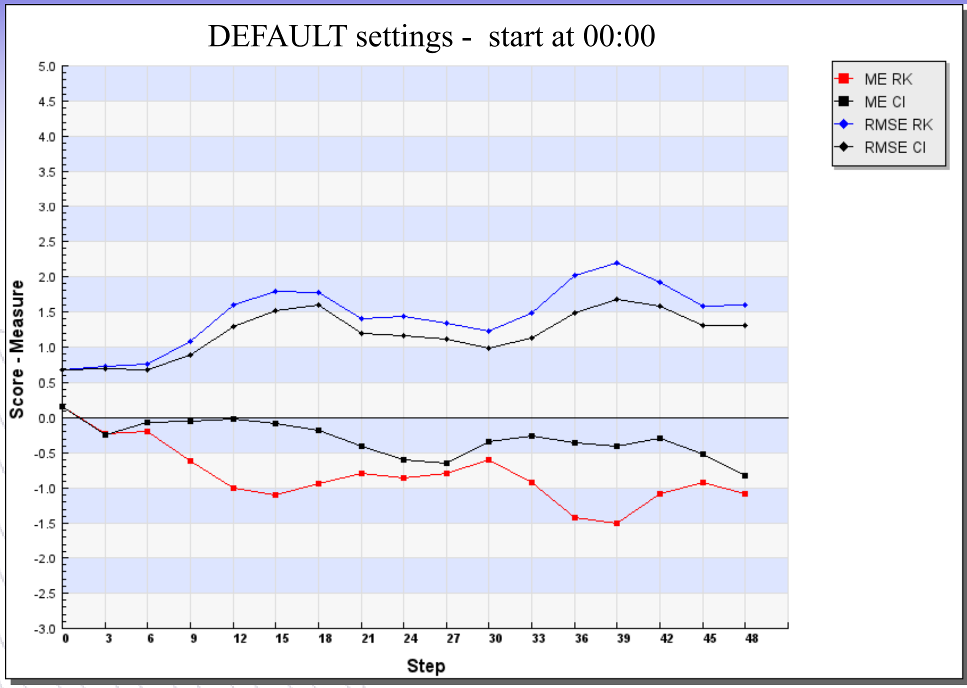


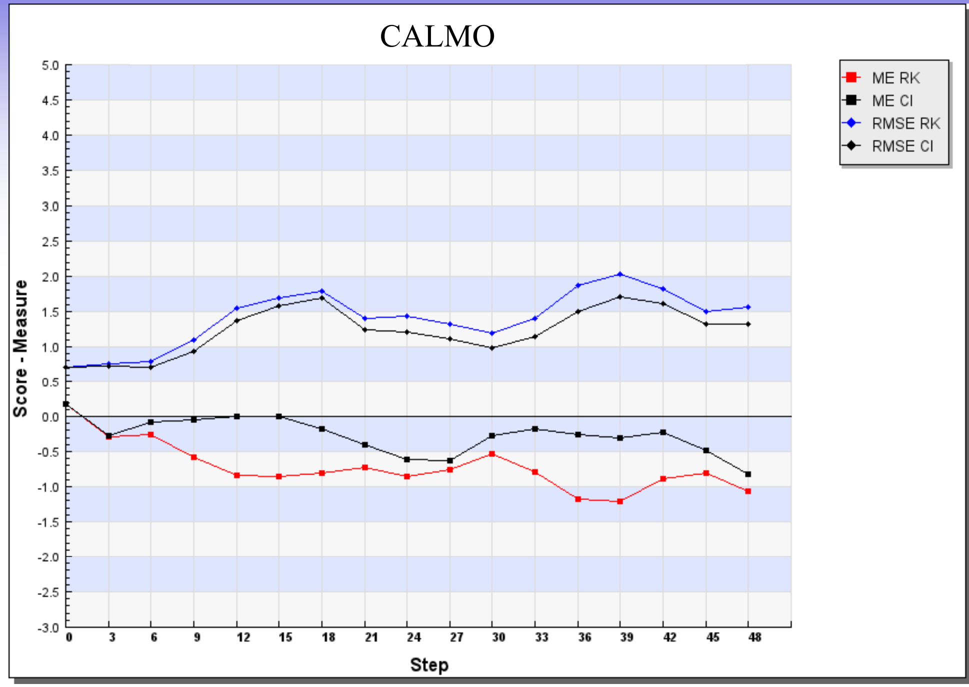
1. RMSE is lower in forecast computed using CI. This offset about 0.5C and remains stable during 48 hours

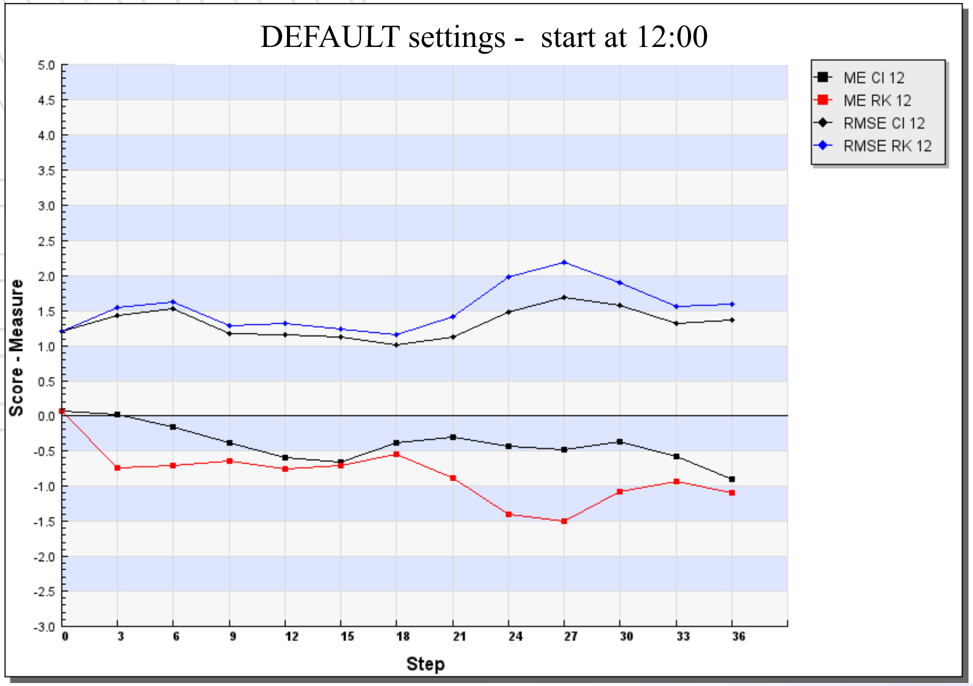
2. In simulations starting at 0:00 ME is comparable in both RK and CI

3. Later start has very little effect on the computed statistic.

Mean sea level pressure [Pa] – surface verification







1. Both ME and RMSE are significantly lower in simulations performed using CI.

2. There is larger difference and grater dependence on the time of day in the RK scores

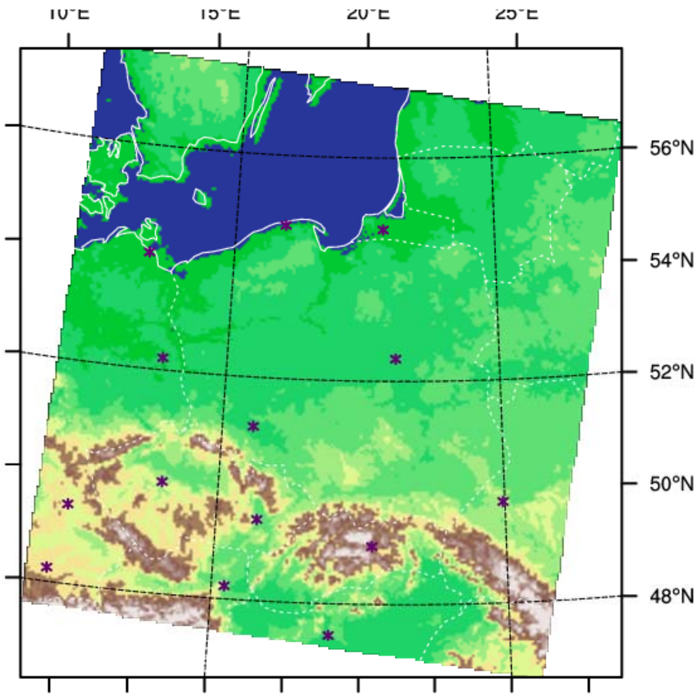
3. There is little improvement in the simulations computed with the optimized (CALMO) parameters.

Verification of first operational CELO simulations over Poland

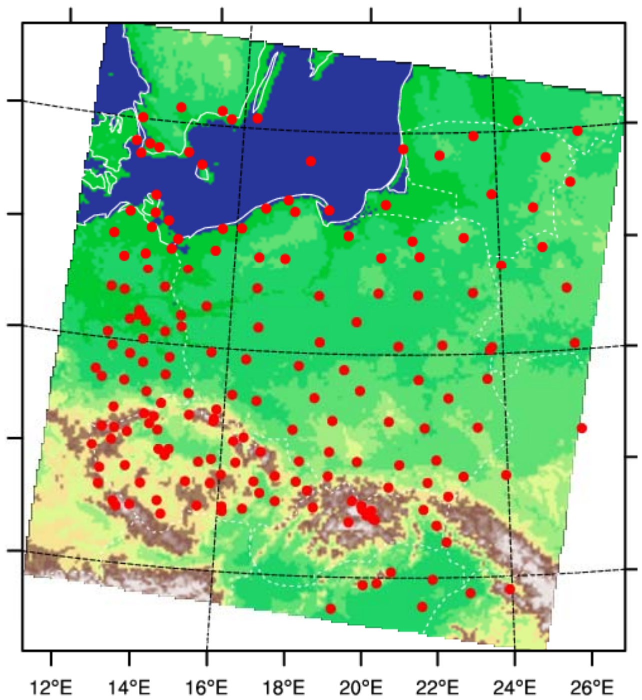
Experiment setup

- COSMO-PL 2k8 domain with 380 x 405 x 50 grid points
- 1-19 August 2018, 0:00 UTC forecasts
- Forecast time span 48 h, with 6 h nudging window
- Verification (VERSUS): SYNOP (182 stations), with TCC (157 stations), with MSLP (154 stations), TEMP (14 stations)

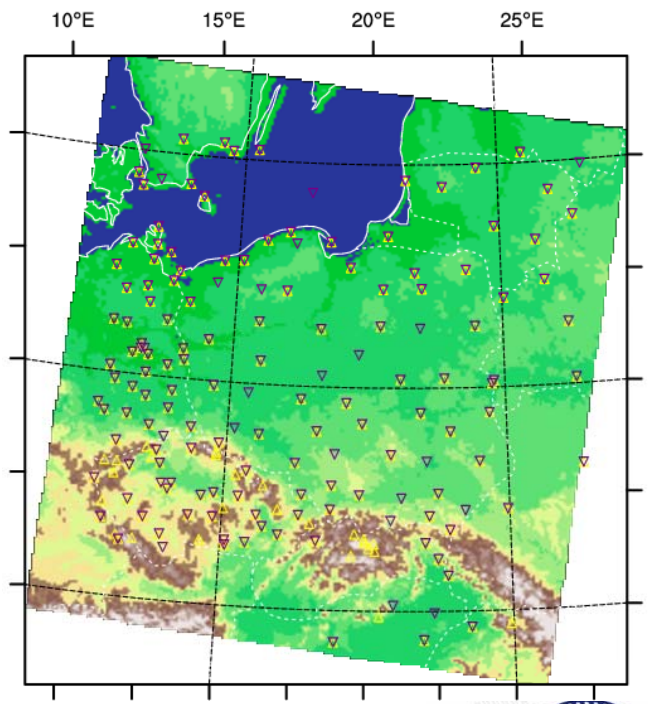
Upper-air sounding stations (14)



SYNOP stations



MSLP obs. (violet) and TCC obs. (yellow)

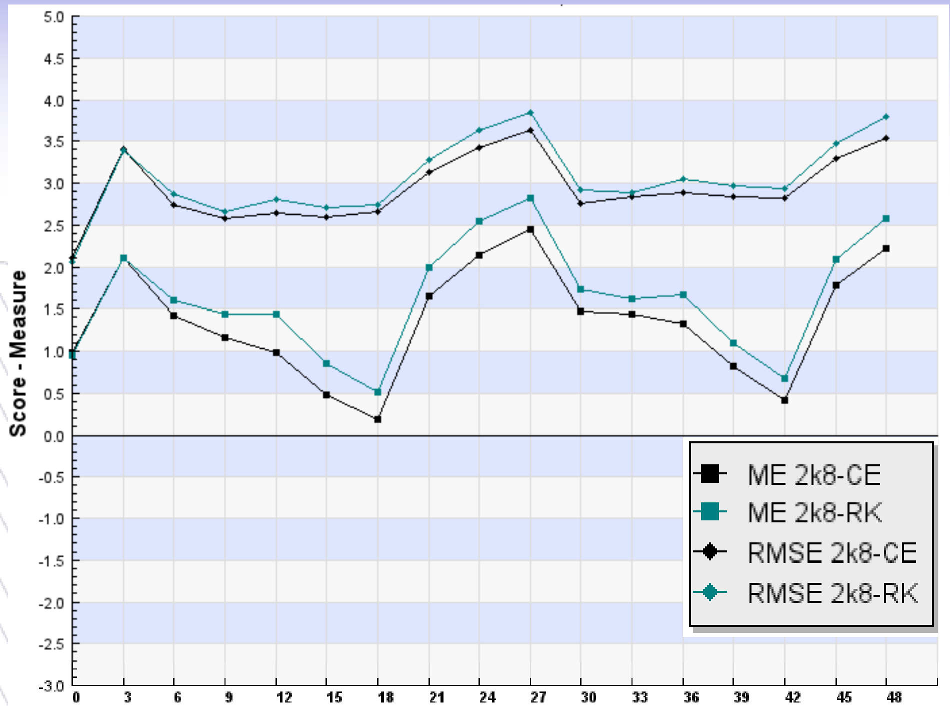


Verification of first operational CELO simulations over Poland

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 ***irunge_kutta=1*** and ***itype_fast_waves=2***
- For COSMO Runge-Kutta 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 CI *dt* = 10 s, for RK *dt* = 20 s

Mean Sea Level Pressure and Temperature at 2m



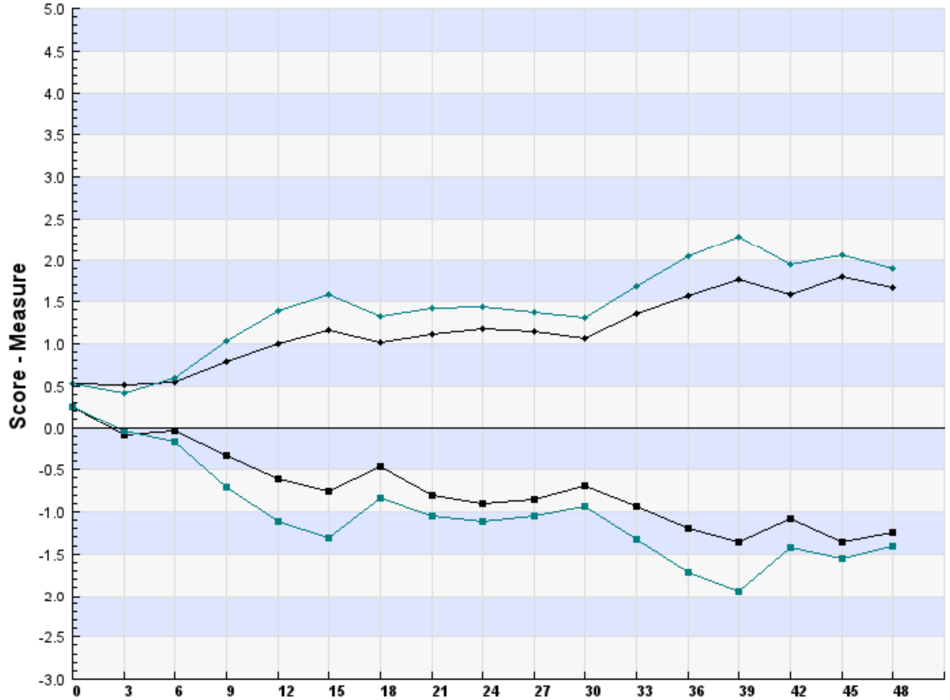
Temperature at 2m

1. The CI 5.04h model slightly outperforms RK 5.04h

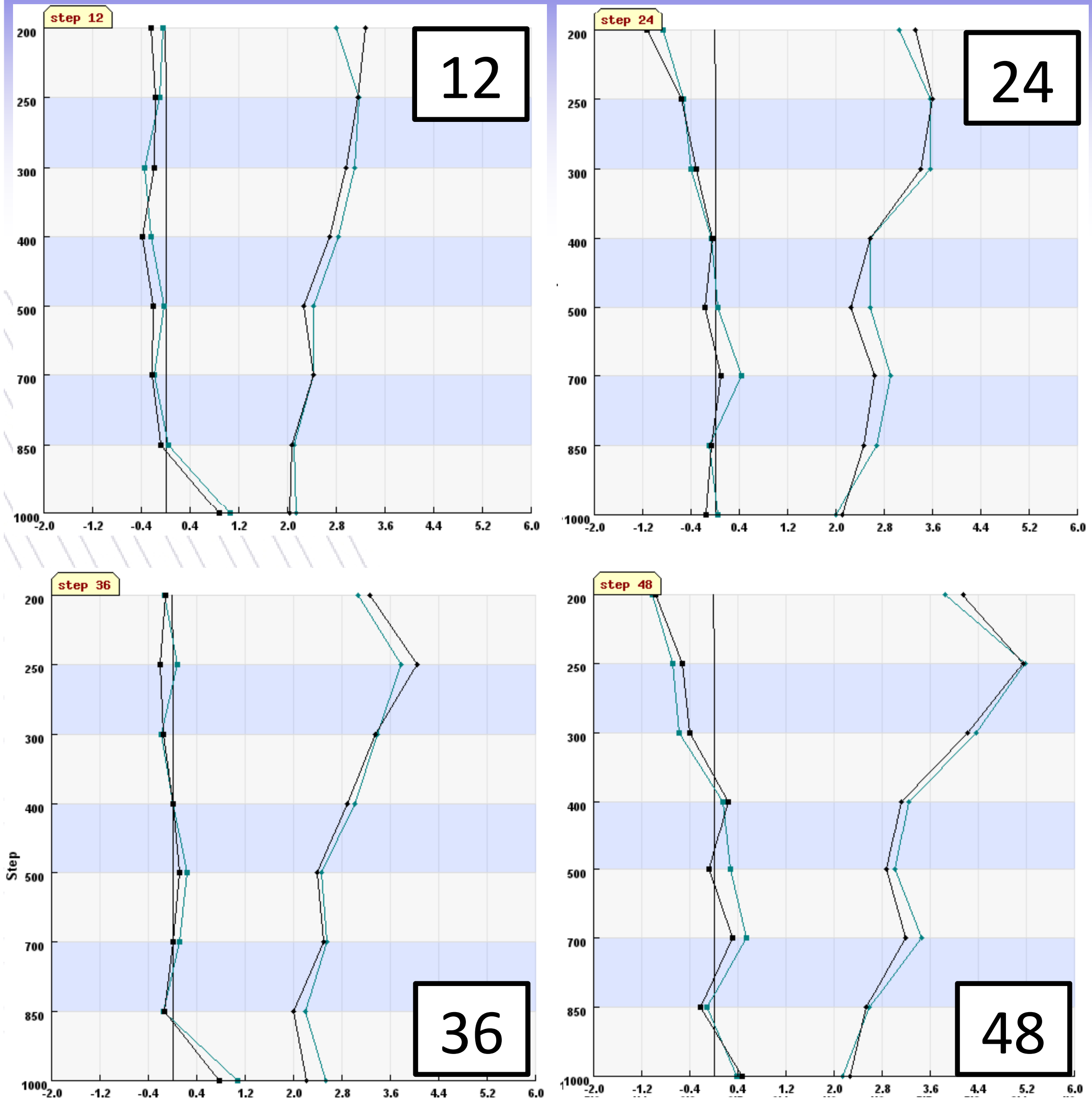
2. The daily cycle is clearly visible in simulations results of both models.

MSLP

The CI 5.04h outperforms RK 5.04h



Wind speed (upper air)

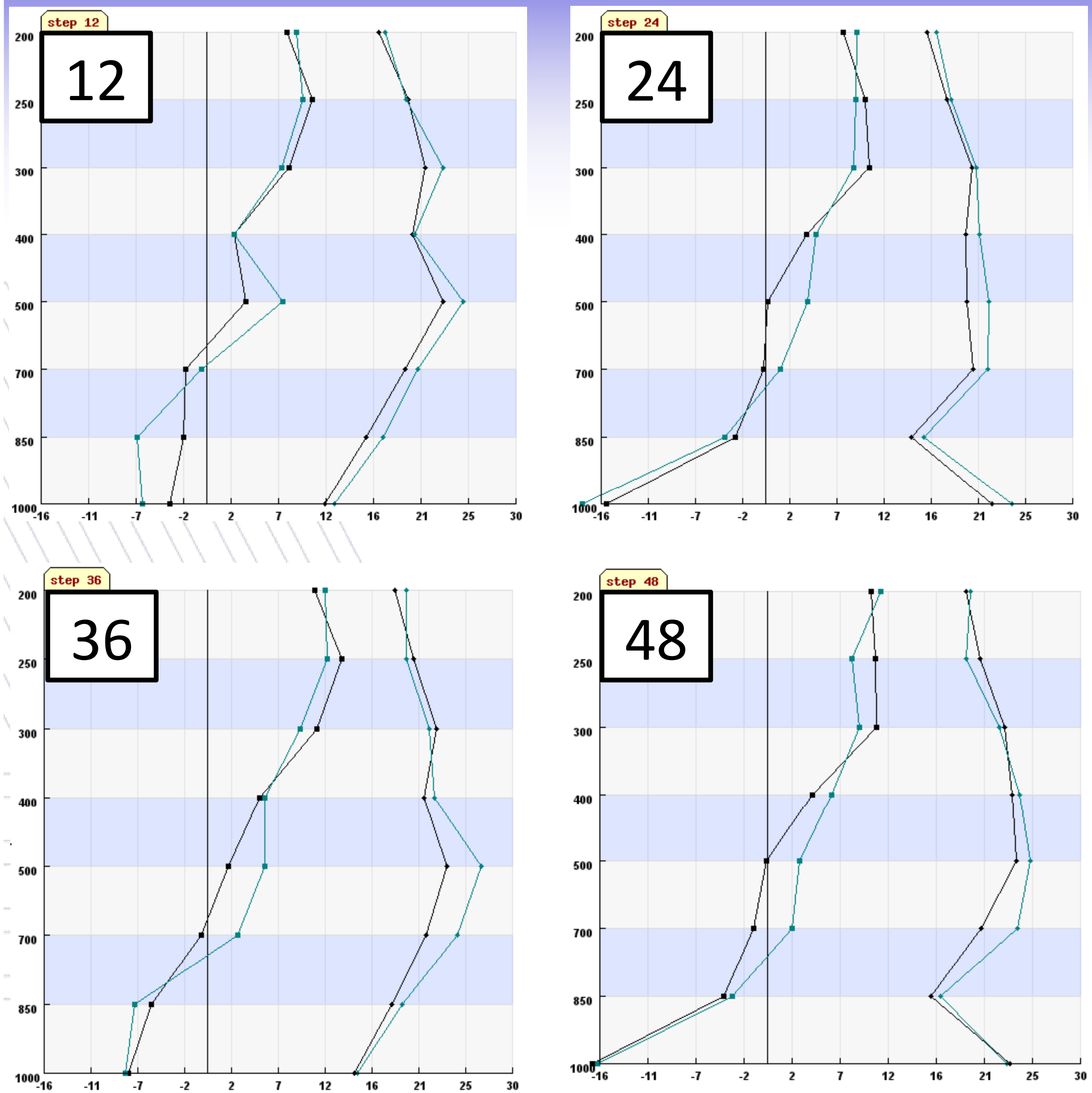


1. Between 1000 and 700 hPa forecasts computed using CI 5.04h are more accurate

2. Between 500 and 300 hPa the scores are similar for both models

3. Above 200 hPa, RK forecast is closer to observations

Relative humidity (upper-air)



1. For most time instants RMSE of CE scores is lower than RMSE of RK (except 300-250 hPa at 36 and 48 hour)

2. Significantly lower Bias is observed in CE results between 1000 and 500 hPa

3. On the other hand, between 300 and 250 hPa Bias is lower in RK simulations.

Conclusions

- **The EULAG model has been successfully coupled to the COSMO framework ver. 5.04h and can be used for operational weather forecasting, with nudging as the assimilation scheme**
- Number of simulations have been performed both with default settings and parameters optimized within CALMO project.
- In most considered cases the numerical forecast computed using CI is closer to observations than RK.
- Operational tests of COSMO-EULAG over COSMO-PL 2k8 domain show that these forecasts are competitive when compared to the forecasts obtained with the default COSMO model.
- The model code with draft scientific documentation and draft user guide handed over to WG2 Coordinator and SCA.

Future work

New Priority Task CCE is proposed to

i.couple EULAG dy-core with COSMO framework ver. 5.05 Deliver code better adjusted to the COSMO Standards,

ii.further improve CI model physical consistency,

iii.test the model in the context of climate simulations, in cooperation with the COSMO CLM Community.

THANK YOU FOR YOUR ATENTION